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The Canadian Entomologist

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The Canadian Entomologist

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The Canadian Entomologist

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Two New Species of Aphids from Eastern Boreal and Arctic Canada (Homoptera: Aphididae)

By W. R. Richards

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This paper includes descriptions of a new species of *Iziphya* Nevsky and one of *Euschizaphis* Hille Ris Lambers. The former genus is well represented in North America, but *Euschizaphis*, which is best known for its association with the Juncaginaceae, has not been previously recorded from the western hemisphere.

Iziphya punctatella, new species

Apterous Viviparous Female.—Colour when alive: Ground colour of head and body yellow with black spots around the bases of most of the setae (Fig. 4). Antennae dark except for the basal half of segment III which is yellow; apex of rostrum dark; legs black except apical two-thirds of tibiae which are colourless. Colour when macerated: Essentially as when alive, but yellow areas colourless or nearly so.

Morphology: Frontal tubercles smooth, poorly developed. Antennal setae pointed except for one or two flabellate ones on segment II; longest antennal setae about equal to the basal diameter of segment III. Length of antennal segments: III, 0.5 mm.; IV, 0.25 mm.; V, 0.26 mm.; VI, 0.15 mm. + 0.27 mm. Rostrum short, not reaching middle coxae; apical segment 0.075 mm. long, with two setae in addition to the usual two or three apical pairs and minute basal pair. Femora with minutely capitate setae on dorsal surfaces. Fore- and middle tibiae with mostly capitate setae and one or two flabellate setae near base; ventral setae pointed. Hind tibiae each with a flabellate seta near base (Fig. 3). First tarsal segment of fore- and middle legs each with five setae on ventral surface; first segments of hind tarsi each with four setae. Arolia broadly flabellate. Length of hind tibiae 0.65 mm. Length of second segment of hind tarsus 0.15 mm. Dorsa of head, thorax and abdominal segments I-VI, and anterior half of tergum VII with strongly flabellate setae; setae mostly rod-shaped on posterior half of tergum VII and whole of VIII. Venter of abdomen with two irregular, transverse rows of pointed setae on each segment. Dorsum of head and of body with scattered, pointed spicules. Venter of body with transverse, spiculose imbrications; legs strongly spiculose. Cauda knobbed, strongly spiculose, with pointed setae. Anal plate spiculose, with pointed setae. Length when mounted 2 mm.

Apterous Oviparous Female.—Colour when alive and macerated: Essentially as in apterous viviparous female.

Morphology: Length of antennal segments: III, 0.45 mm.; IV, 0.24 mm. — 0.275 mm.; V, 0.275 mm. - 0.28 mm.; VI, 0.15 - 0.2 mm. + 0.27 mm. Setae on legs mostly pointed, sometimes one or two capitate or flabellate ones near bases on tibiae on dorsal surfaces. Hind tibiae with many circular sensoria on the slightly swollen, pigmented, apical half or two-thirds. First tarsal segments each with five setae on ventral surfaces. Length of hind tibia 0.6 mm. Length of second segment of hind tarsus 0.1 mm. Distribution of dorsal, flabellate setae similar to that in apterous viviparous female, but with rod-shaped setae on terga V-VIII.

Abdominal segments V-VII with a large, ventral, cribriform plate on each side, that tends to encircle the ventral margin of the cornicles. Length when mounted 1.7-2 mm. Otherwise essentially as in apterous viviparous female.

Apterous Male.—Colour when alive: Head and body yellow, with lightly fuscous intersegmental areas and with or without very weakly pigmented spots on the bases of some dorsal setae (Fig. 1). Cornicle dark. Colour when macerated: Essentially as when alive.

Morphology: Lengths of antennal segments: III, 0.45 mm.; IV, 0.25 mm.; V, 0.2 mm. - 0.225 mm.; VI, 0.175 mm. + 0.225 mm. Antennal segment III with 13-18 secondary sensoria, IV with 4-11, V with 6-9. First tarsal segments each with five ventral setae. Length of hind tibia 0.5 mm. - 0.55 mm. Dorsal flabellate setae poorly developed, restricted to head, thorax and anterior abdominal segments. Cauda knobbed, somewhat triangular. Length when mounted 1.45 mm.

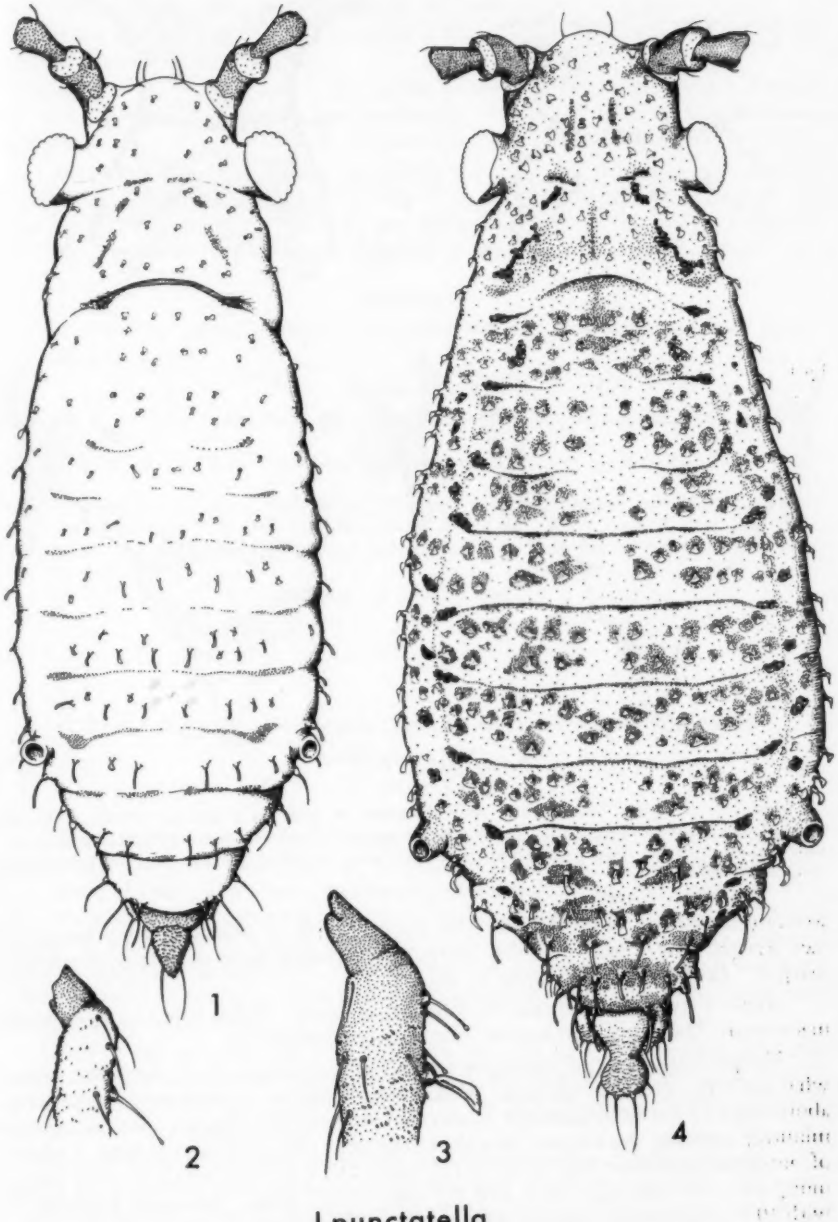
Holotype.—Apterous viviparous female. Fort Chimo, Quebec, August 17, 1959 (W. R. Richards), on *Carex bigelowii* Torr. No. 7284 in Canadian National Collection. Paratypes: Nine oviparous females, two males. Same data as for holotype.

Comments.—This species can be most readily recognized by the isolated, deeply pigmented spots around the bases of most of the dorsal setae. In this respect *punctatella* resembles *I. punctata* H. R. L., but in the latter species most of the lateral spots on the thorax coalesce producing a striking, pale, median vitta. The dorsal, basal chaetotaxy of the hind tibia is similar to that of *I. albipes* Richards, but *albipes* lacks flabellate setae (Fig. 3).

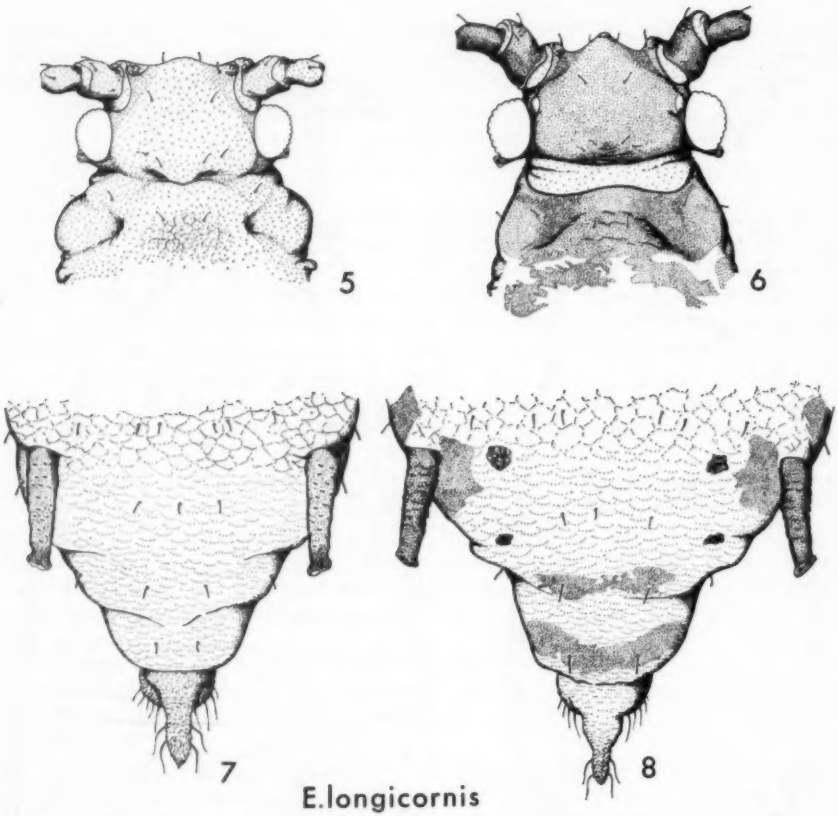
Euschizaphis longicornis, new species

Apterous Viviparous Female.—Colour when alive: Unknown. Colour when macerated: Light brown, antennae, tarsi, and apical portion of cornicles darker brown.

Morphology: Frontal tubercles well developed, each with a small, but distinct, irregular, dorsal protuberance (Fig. 5). Disc of head with six capitate setae, none of which exceeds the basal diameter of antennal segment III. Antennal setae blunt or minutely capitate, the longest ones equal to half the basal diameter of segment III. Antennae without secondary sensoria. Lengths of antennal segments: III, 0.23 mm. - 0.25 mm.; IV, 0.15 mm.; V, 0.13 - 0.14 mm.; VI, 0.075 mm. - 0.08 mm. + 0.3 - 0.35 mm. Rostrum barely reaching middle coxae; apical segment 0.11 mm. long, with two setae in addition to the usual two or three apical pairs and minute basal pair. Setae on dorsal surfaces of femora and tibiae mostly minutely capitate, pointed on ventral surfaces; the longest setae on legs about equal to apical diameter of hind tibia. First tarsal segment of fore- and middle legs each with three ventral setae; two setae ventrally on each first tarsal segment of hind tarsi. Length of hind tibia 0.7 mm. Length of second segment of hind tarsus 0.1 mm. Setae on dorsum of thorax the same size and shape as those on disc of head. Setae on dorsum of abdomen similar in size and shape to those on disc of head, arranged in six longitudinal rows on terga I-V; arranged otherwise on terga VI-VIII (Fig. 7). Cornicles cylindrical, with a well developed flange and dispersed, spiculose imbrications; 0.225 mm. long. Lateral abdominal tubercles absent. Dorsum of thorax and abdominal terga I-V with fairly well developed reticulations; spiculose imbrications on abdominal terga V-VIII, on venter of abdomen and on posterior surfaces of femora; tarsi with smooth imbrications. Cauda short, slightly constricted before apex, strongly spiculose, with four curved, pointed setae. Anal plate strongly spiculose, with curved, pointed setae. Genital plate with spiculose imbrications that are much more



Figs. 1-4. 1, Dorsal view of male; 2, Basal portion of right hind tibia of male; 3, Basal portion of right hind tibia of apterous viviparous female; 4, Dorsal view of apterous viviparous female.



Figs. 5-8. 5, Dorsal view of head and prothorax of apterous viviparous female; 6, Dorsal view of head and prothorax of alate viviparous female; 7, Dorsal view of apical portion of abdomen of apterous viviparous female; 8, Dorsal view of apical portion of abdomen of alate viviparous female.

strongly developed along the posterior margin; with 12 pointed setae arranged in two irregular rows near posterior margin, two central setae and six near anterior margin. Length when mounted 1.7 mm.

Alate Viviparous Female.—Colour when alive: Unknown. Colour when macerated: Abdomen light brown, elsewhere darker brown.

Morphology: Frontal tubercles fairly well developed, with the usual, somewhat scabrous, dorsal projection. Discal setae minutely capitate, the longest ones about equal to the basal diameter of antennal segment III (Fig. 6). Antennal setae minutely capitate, the longest ones about the same size as the discal setae. Lengths of antennal segments: III, 0.325 - 0.375 mm.; IV, 0.2 - 0.22 mm.; V, 0.15 - 0.175 mm.; VI, 0.06 mm. - 0.1 mm. + 0.375 mm. - 0.395 mm. Antennal segment III with 10 - 12 secondary sensoria, segments IV and V sometimes with one sensorium. Rostrum not reaching middle coxae, apical segment 0.1 mm. long, with one or two setae in addition to the usual two or three apical pairs and minute basal pair. Dorsal surfaces of femora and tibiae with minutely capitate setae, pointed setae elsewhere. Medius of wings with one furcation. Length of hind tibia 0.825 mm.

- 0.85 mm. Length of second segment of hind tarsus 0.12 mm. Length of cornicle 0.2 mm. Length when mounted 2 mm. Otherwise essentially as in the apterous viviparous female.

Holotype.—Apterous viviparous female. Frobisher Bay, Baffin Island, August 10, 1929 (W. R. M. Mason), host unknown. No. 7285 in Canadian National Collection. Paratypes: Four alate viviparous females. Same data as for holotype.

Comments.—This species can be readily distinguished from the type species, *E. palustris* (Theobald), by the differences in the lengths of the antennae. In *E. palustris* the antennae are less than one-third the length of the body (Theobald 1929: 343), whereas they are more than half as long as the body in *E. longicornis*.

Summary

Two new species of Aphididae are described and illustrated and their structural affinities noted.

References

Theobald, V. F. 1929. Aphididae of Great Britain III. Invicta Press, London, England 364 p.: 343.

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Hille Ris Lambers, D. 1960. Some new genera and species of aphids from Canada (Homoptera: Aphididae). *Canad. Ent.* 92: 257-259.

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(Received July 14, 1960)

A Field Key to the North American Species of *Hylobius* (Curculionidae)[1]

By R. J. FINNEGAN[2]

There are five known North American species in the genus *Hylobius*; *H. pales* (Hbst.), *H. congener* Dalla Torre, *H. pinicola* (Couper), *H. radicis* Buch., and *H. warreni* Wood. In recent years four of these species have increased considerably in economic importance in central and eastern Canada and the eastern United States; *H. pales* and *H. radicis* attacking pines and *H. pinicola* and *H. warreni* attacking spruces and pines. *H. congener* occurs only in small numbers and little is known about its ecology. It is important, therefore, to be able to separate these species readily in the field.

Since at the present time it is necessary to refer to three separate keys for proper identification of the species concerned, the following key, based mainly on the work of Leconte (2), Buchanan (1), and Wood (4), has been compiled and has been used satisfactorily.

Although the five species are readily separated into two groups, the individual species within each group are very similar and may easily be confused. *H. pales*, *H. congener*, and *H. radicis* are smaller than *H. pinicola* and *H. warreni*, and differ in general appearance from them. The shape of the femora and the presence or absence of teeth on them, as indicated in the following key, are also important distinguishing characters of the two groups.

1 Contribution No. 645, Forest Biology Division, Research Branch, Department of Agriculture, Ottawa, Canada.

2 Forest Insect Laboratory, Sault Ste. Marie, Ontario.

In 1934, Buchanan (1) described *H. radicis* as a new species and presented a synoptic key for *H. pales*, *H. congener*, and the new species *H. radicis*. These three weevils constituted all the North American species of the genus *Hylobius* known at that time. Recently, Wood (4) in a review of the North American allies of the Eurasian species *Hylobius piceus* (DeGeer), invalidated the genus *Hypomolyx* of Leconte by separating the single Holarctic species in the genus, *Hypomolyx piceus* (DeGeer), into two separate species and transferring them to the genus *Hylobius* under the names *H. piceus* (palaearctic) and *H. pinicola* (nearctic). In the same paper he described a new North American species, *H. warreni*, which is apparently closely related to *H. pinicola*. He also presented a key separating the three species involved, viz., *H. piceus*, *H. pinicola*, and *H. warreni*. More recently, Warren (3) described in detail the external anatomy of the adult *H. warreni*, comparing it with *H. pinicola*. Many significant differences are revealed in this paper but, except for those described previously by Wood (4), these can only be observed by dissecting the adult insect and thus are unsuitable for a field key.

Key

1. Femora club-shaped, strongly toothed 2
   Femora feebly club-shaped, not toothed 4
2. Scutellum virtually glabrous; anterior face of at least the hind femur almost always with a narrow, shallow, median groove in about basal third; inner edge of fore tibia of male with a fringe of white hair, the length of some of the longer hairs equal to width of tibia. Length 5.8 to 9.0 mm. ..... *congener* Dalla Torre
   Scutellum normally covered by a dense coating of seta-like scales; hind femur rarely with even a trace of a groove; male without tibial fringe as above 3
3. Size smaller, 5.8 to 11.3 mm.; head normally with a line or spot of coarser seta-like scales on vertex or on front; punctures immediately behind interocular puncture more or less strongly coalescent to form short, irregular rugae; hind tibial uncus of male broad, parallel-sided, very broadly rounded at apex ..... *pales* (Hbst.)
   Size larger, 9.4 to 13.0 mm.; head without a line or spot of scales on front of vertex; punctures behind interocular puncture generally separated by narrow intervals, or at most only feebly coalescent; hind tibial uncus of male narrow, sides generally convergent to the sub-acute apex ..... *radicis* Buch.
4. Rostrum rather stout, less than 2.6 times as long as wide, noticeably wider distally; apical umbones of the elytra obscure or entirely undefined; metathoracic wings short, not extending beyond the posterior margin of first visible abdominal sternite *warreni* Wood
   Rostrum slender, more than 2.9 times as long as wide, not wider distally; apical umbones of elytra prominent; metathoracic wings long extending well beyond elytral apex ..... *pinicola* (Couper)

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(1) Buchanan, L. L. 1934. An apparently new species of North American *Hylobius*, with synoptic key (Coleoptera: Curculionidae). *Proc. Ent. Soc. Wash.*, 36: 252-256.

(2) LeConte, J. L. 1876. The Rhynchophora of America, north of Mexico. Am. Phil. Soc. 15: I-IX, 1-455.

(3) Warren, G. L. 1960. External anatomy of the adult of *Hylobius warreni* Wood (Coleoptera: Curculionidae) and comparison with *H. pinicola* (Couper). *Canad. Ent.* 92: 321-341.

(4) Wood, S. L. 1957. The North American allies of *Hylobius piceus* (DeGeer) (Coleoptera: Curculionidae). *Canad. Ent.*, 89(1): 37-43.

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The North American Species of the Family Opomyzidae (Diptera: Acalypterae)

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The family Opomyzidae is composed of small (2.0 mm. - 4.4 mm.), slender, usually brown or reddish flies; the wings have at least an apical spot and are usually more heavily marked. Several species of the genus *Geomyza* have the wings reduced and are nearly flightless. The few species whose larvae are known feed in grass stems. Some are of minor economic importance in Europe but none have been so reported in North America.

In the present paper 13 species of three genera of Opomyzidae are recorded from North America. Of these, five species, all belonging to *Geomyza*, are described as new. *Opomyza*, with two species obviously introduced from the Palaearctic region, and *Anomalochaeta*, with one Holarctic species, are definitely recorded from North America for the first time. Of the ten species of *Geomyza*, eight are endemic, one is obviously introduced from the Palaearctic region, and one is apparently naturally Holarctic.

Previous Studies

Melander (1913) presented the only revision of the North American species; he recorded six nominal species. Three of these are included in the present paper, all under *Geomyza*. Two, *G. combinata* (L.) and *G. venusta* (Mg.), are European species; they may occur here but the identity of the former is uncertain (see below under *G. balachowskyi* Mesnil) and I have seen no North American specimens of the latter (as defined by Mesnil, 1934).

Excluded Species

Opomyza signicosta Walker 1861 (incorrectly cited as *nigricosta* by Aldrich, 1905) was doubtfully referred to *Opomyza* by Melander. Mr. R. L. Coe of the British Museum (Natural History) has informed me, in *litt.*, that the type is not in that museum; it is presumably lost. However, Malloch and McAtee (1924) synonymized *signicosta* with *Leucophenga varia* (Walker) 1849 (Drosophilidae); this synonymy is accepted here. *Geomyza subdola* Johnson 1922 is a species of *Mycetaulus* (Piophilidae). I have examined the holotype and one of the paratypes in the Museum of Comparative Zoology, Cambridge; my colleague Mr. J. F. McAlpine has examined one of the paratypes and considers it to be of a species of *Mycetaulus* not otherwise described.

Relationships and Distribution

Melander (1913) treated those genera of the present paper known to him as a small part of the subfamily Geomyzinae of the family Muscidae. Curran (1934) included them in the family Opomyzidae, but also included those Nearctic genera now referred by most authors to the Anthomyzidae and Tethinidae. European authors (e.g. Czerny, 1928; Hennig, 1939, 1958; Collin, 1945; Hackman, 1958) are unanimous in treating the three genera of the present paper as a separate family. This course is followed here.

Most students have considered the Opomyzidae to be very closely related to the Anthomyzidae; I would agree with this although my knowledge of the latter group is limited. Hennig (1939, 1958) listed a number of characters in which *Opomyza* and *Geomyza* differ from the genera of Anthomyzidae examined

by him. In the latter paper he suggests that the two families may not be closely related. However, a free sixth tergite in the male, present in the Anthomyzidae examined by Hennig but absent in *Opomyza* and *Geomyza*, is present in *Anomalochaeta*, an undoubted Opomyzid, as a narrow but distinct sclerite. In the other characters listed by Hennig, including those of the male terminalia (absence of free surstyli, presence of an epiphallus) and of the female terminalia (presence of only six pairs of abdominal spiracles, non-fusion of tergite seven and sternite seven, slight compression of segment eight and succeeding structures) *Anomalochaeta* agrees with *Opomyza* and *Geomyza* rather than with the Anthomyzidae.

The family is best developed in the temperate parts of the Holarctic region, particularly in central Europe and western North America, but a few species from other regions have been referred to it. Of these *Mutilloptera alluaudi* Hendel 1917, from Mt. Kilimanjaro (2600-2800 m.), appears, from the description and figure, to be a species of *Geomyza* very similar to *G. apicalis* (Mg.). The other species are placed in distinct genera – *Tenuia* Malloch 1926 (Philippine Is.), *Teratomyza* Malloch 1933 (New Zealand and Chile), *Scelomyza* Séguy 1934 (Kenya) and *Neogeomyza* Séguy 1934 (Kenya (Séguy); Philippine Is. (Frey, 1958)). All these except the Philippine species of *Neogeomyza* have the mesopleuron bare, and all (particularly *Tenuia*) differ markedly in other respects from the Opomyzidae as defined below. The family should perhaps be redefined to include some or all of them, as Harrison (1959) has done to include *Teratomyza*. A comparative study of these genera, and of those referred to the Anthomyzidae, is needed.

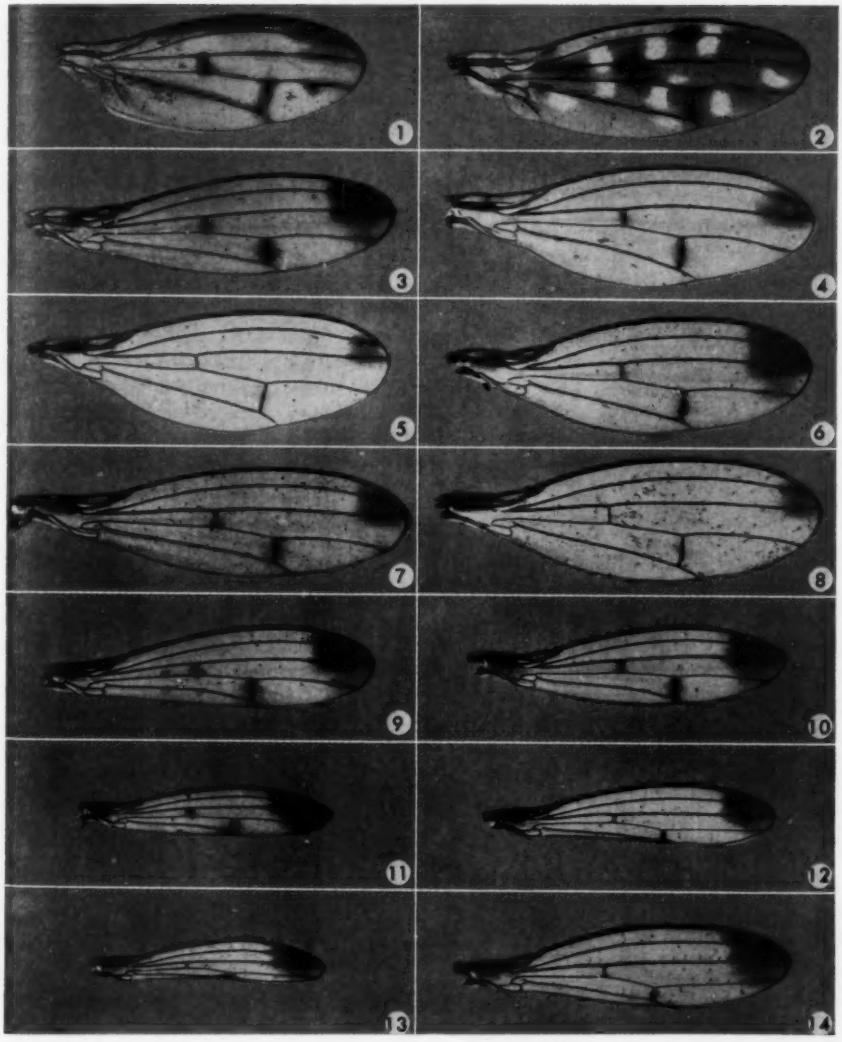
Acknowledgements

Most of the material recorded here is in the Canadian National Collection, Ottawa (C.N.C.). Important collections have also been studied through the kindness of Mr. C. W. Sabrosky of the United States National Museum (U.S.N.M.), Dr. M. R. Wheeler of the University of Texas, Austin, Mr. G. C. Steyskal of Grosse Ile, Mich., Dr. A. L. Melander of Riverside, Calif., Mr. P. H. Arnaud, Jr. of the California Academy of Sciences (C.A.S.), Dr. P. J. Darlington, Jr. of the Museum of Comparative Zoology, Cambridge (M.C.Z.), Dr. F. H. Rindge of the American Museum of Natural History (A.M.N.H.), Dr. H. J. Grant, Jr. of the Academy of Natural Sciences of Philadelphia (A.N.S.P.), Dr. W. Hackman of the University Zoological Museum, Helsingfors, Finland (U.Z.M.H.), and Dr. F. Kühlhorn of the Zoologische Staatssammlung, Munich. I am particularly indebted to Dr. Melander for the loan of a syntype of *Geomyza monostigma* Melander from his personal collection, and to Dr. Wheeler for permission to deposit the type of *G. vespertina* n. sp. in the C.N.C.

Family Diagnosis

The family Opomyzidae may be described as follows (the characters in italics, will, in combination, separate the family from all other Acalypterae):

Length 2.0 mm. to 4.4 mm. Slender to very slender; yellow, reddish, brown or blackish; shining to pollinose; wings (Figs. 1-14) always with at least an apical spot, usually with more extensive markings. Head (Figs. 15-17) with front slightly narrowed anteriorly; interfrontal area weakly sclerotized, slightly depressed, strongly narrowed anteriorly and margined by minute hairs; upper half of posteranium concave. One orbital bristle; ocellars and inner and outer verticals strong; *postverticals usually absent, if present divergent;* one or two rows of peristomal hairs present below eye; *no distinct vibrissa present but sometimes one or more peristomal hairs enlarged and bristlelike.* Antenna short, third



Figs. 1-14. Left wing. 1, *Opomyza petrei* Mesnil, ♂, Cultus Lake, B.C. 2, *Anomalochaeta guttipennis* (Zett.), ♂, Christopher L., Sask. 3, *Geomyza balachowskyi* Mesnil, ♂, Lockeport, N.S. 4, *G. lurida* (Lw.), ♂, Juskatla, Q.C.I., B.C. 5, *G. monostigma* Melander, ♀, Headwaters Pescadero Cr., San Mateo Co., Calif. 6, *G. monticola* n. sp., ♂ paratype, Elkwater, Alta. 7, *G. vespertina* n. sp., ♂ holotype, Arboretum, Arcadia, Calif. 8, *G. parvistigma* n. sp., ♀ paratype, Robson, B.C. 9, *G. velata* n. sp., ♂ paratype, Sturgis, Sask. 10, 11, *G. apicalis* (Mg.), ♂ ♂, Ottawa, Ont. 12, 13, *G. coquilletti* (Hend.), ♂ ♂, St. Victor, Sask. 14, *G. coquilletti* (Hend.), ♀, St. Victor, Sask. (Figs. 1, 4, 5 X 11.5, Figs. 2, 3, 6-14 X 19).

segment produced downward and distinctly pubescent; arista pubescent, the dorsal hairs often much longer than the ventral. Palpus moderately large, broadened. Mesonotum strongly bristled, with one humeral, one posthumeral, two notopleurals, one prealar, one strong and one weak postalar, *one presutural dorsocentral* and two or three postsutural dorsocentrals; acrostichal hairs very short, appressed, in about four to ten irregular rows. Scutellum haired or bare above, with four bristles, the basal pair usually weak. *Mesopleuron posteriorly with many hairs and one strong bristle; pteropleuron with a few hairs,* rarely with a weak bristle; sternopleuron with a strong bristle. Wing (Figs. 1-14) moderately broad to extremely narrow, often with alula and anal lobe absent and the cells of the posterior half of the wing narrow. *Costa broken only at apex of* Sc, *the latter extremely weak on apical half and joining costa some distance before apex of* R_1; R_1 with a weak upward projection at level of costal break; costa extending to end of M_{1+2} (fourth vein); second basal and discal cells incompletely separated; *anal cell present,* small; anal vein either present and incomplete or absent. Legs weakly bristled; tibiae without dorsal preapical bristle; mid tibia with long strong, ventral bristle at apex. Males of *Opomyza* and *Geomyza* with tergite six absent, only one segmental complex (sternites six to eight) present between segments five and nine; male of *Anomalochaeta* with a narrow, free tergite six lying immediately behind tergite five, and with sternites six to eight as in the other two genera. Tergite nine, sternite nine and associated structures, and cerci all symmetrical in structure. Surstylus not articulated, apparently fused with lower lateral margin of tergite nine to form a surstylar process of varying form. Aedeagus (Fig. 25) elongate, heavily sclerotized, very complex, differing slightly in structure in the three genera but varying very little within a genus. Cerci large, elongate, usually rather weakly sclerotized. Female with abdominal tergites and sternites one to seven well developed, not fused; segment eight and cerci slightly compressed but not heavily sclerotized, slender, sometimes elongate, separated from segment seven by an extensive membrane; tergite eight and sternite eight separate, the former longitudinally divided. Hypoproct and epiproct not present as separate sclerites. Abdomen with six pairs of spiracles. Spermathecae two, subspherical.

In the taxonomic section below, only the more important references from the European literature are given for the genera and for the Holarctic and introduced species. European synonyms are not included.

Key to North American genera of Opomyzidae

1. Postvertical bristles present; wing (Fig. 2) dark with about ten rounded hyaline spots ..... *Anomalochaeta* Frey
   Postvertical bristles absent; wing (Figs. 1, 3-14) clear with costal margin and some veins darkened or with only apex and crossveins darkened 2
2. Wing with alula and anal angle obsolete; disc of scutellum bare, the basal scutellar bristles very short; arista long-haired above, short-haired below; one or more peristomal hairs enlarged, bristle-like ..... *Geomyza* Fallén
   Wing with alula and anal angle well developed; disc of scutellum haired, the basal bristles subequal to the apicals; arista pubescent; peristomal hairs all short and fine ..... *Opomyza* Fallén

Opomyza Fallén

Opomyza Fallén, 1820, Dipt. Suec. Opomyz., p. 10; Melander, 1913, J. N.Y. ent. Soc. 21: 284; Czerny, 1928, Flieg. pal. Reg. 54c: 3; Curran, 1934, Fam. Gen. N.A. Dipt., p. 331; Mesnil, 1934, Rev. franç. Ent. 1: 201; Collin, 1945, Ent. Rec. 57: 13; Hackman, 1958, Not. ent., Helsingf. 38: 115.

Type species: *Musca germinationis* Linnaeus, 1758, the first of the three originally included named species, by designation of Westwood (1840, p. 152).

Moderately stout, yellowish-brown to blackish-brown, pollinose; wing (in Nearctic species) with most of costal margin, crossveins and most longitudinal veins clouded. Length 3.3 to 4.4 mm. Head as in Fig. 15; cheek broad, especially posteriorly, with two rows of short, weak, subequal peristomal hairs; postverticals absent; arista short-pubescent. One presutural and three postsutural dorsocentrals. Scutellum with a few hairs above, with four strong bristles. Pteropleuron with a few hairs, without bristle. Wing (Fig. 1) moderately broad; alula and anal lobe well developed; anal vein present, ending shortly before wing margin, with a scarcely discernible fold extending from its apex parallel with wing margin. Male (of Nearctic species) with several rows of short, moderately strong bristles on posteroventral surface of mid tibia. Male with tergite six absent. Tergite nine (Figs. 21, 23) large, with lower margin produced slightly posteroventrad and ending in a short, posteriorly-directed tooth-like process. Cercus large, well-sclerotized, its apex sometimes with many stiff setulae. Female terminalia as described above for family.

Approximately nine species of the genus are known from the Palaearctic region. The two species known to occur in North America are undoubtedly introduced. *O. petrei* Mesnil is well established in southern coastal British Columbia and on Vancouver Island. *O. germinationis* (L.) is known from a single female from Nova Scotia. *O. florum* (Fabricius) 1794 is as common in western Europe as *O. petrei;* it has not been found in North America but may be introduced in the future. It may be distinguished from all known species by its wing markings – the costa is clouded on only the apical one-eighth, the last section of vein M_{1+2} bears a small posterior spur which is covered by a small brown cloud, vein R_{4+5} is clouded only at its apex, and the crossveins are clouded.

Key to North American species of *Opomyza*

1. Abdomen (Fig. 41) with dark median stripe which expands on posterior part of each tergite, occasionally abdomen entirely dark; male, apex of cercus (Fig. 22) with sparse, fine setae ..... *germinationis* (L.)
   Abdomen (Fig. 42) with dark median stripe which tapers almost uniformly from anterior margin of tergite two to posterior margin of tergite four; male, apex of cercus (Fig. 24) with dense, short, stiff black setulae ..... *petrei* Mesnil

***Opomyza germinationis* (Linnaeus)**

Figs. 15, 21, 22, 41

Musca germinationis Linnaeus, 1758, Syst. Nat., ed. 10, p. 600.
Opomyza germinationis, Czerny, 1928, Flieg. pal. Reg. 54c: 4; Mesnil, 1934, Rev. franç. Ent. 1: 202; Balachowsky and Mesnil, 1935, Ins. nuis. Plantes cult., p. 1026; Coll'n, 1945, Ent. Rec. 57: 14; Hackman, 1958, Not. ent., Helsingf. 38: 116.

Male.–Length 3.3 to 4.4 mm. Head (Fig. 15) yellow to yellow-brown, front sometimes yellow-orange, upper half of occiput sometimes blackened; face and cheeks slightly silver-pollinose. Antenna yellow-orange, apical half of third segment brownish. Thorax yellow-brown to brown, dull, slightly grey-pollinose, darker posteriorly. Mesonotum with broad, median, brown to dark-brown stripe which continues onto scutellum and which has its central third greyish anteriorly, and with narrow brownish stripe laterad of dorsocentrals. Pleuron with brownish stripe along upper margin. Wing (Fig. 1) with broad anterior margin from apex of R_1 to apex of R_{4+5} brown, apical half of M_{1+2} (fourth vein) with narrow brown cloud, other longitudinal veins often faintly clouded, crossveins distinctly clouded. Legs dull yellow to yellow-brown. Abdomen slightly grey pollinose, usually entirely brown to blackish, in paler specimens with each of tergites one to five yellowish antero-laterally (as in Fig. 41). Tergite nine (Fig. 21) with posterior margin curving gently into

tooth-like process, ventral margin with only a few bristles. Cercus evenly curved posteriorly, tapering to a slender, pointed apex, the latter with only short, slender bristles and hairs (Fig. 22).

Female.—Length 3.7 to 4.4 mm. Very similar to male and equally variable in colour. Abdomen often mostly or entirely blackish brown, sometimes extensively yellowish but with median and posterior portion of tergites one to six, and with extreme lateral margins of all tergites, dark (Fig. 41).

Distribution.—Nova Scotia (obviously introduced); Europe.

Specimens examined.—1 ♀, Lockeport, N.S., 20.VII.1958 (J. R. Vockeroth) [C.N.C.]; 29 ♂♂, 68 ♀♀, England, Germany, Austria, Trieste [in many collections].

Type locality and type.—Sweden. Type presumably in collection of Linnaean Society, London.

Discussion.—The description and figures of the male were based upon European specimens. *O. germinationis* has been reared in England from 12 species of Gramineae of the genera *Festuca, Lolium, Poa, Agrostis, Phleum, Alopecurus, Phalaris* and *Holcus* (Nye, 1958); Balachowsky and Mesnil have recorded it also from wheat (*Triticum aestivum* L.). These authors have described and figured the larva. Host records published by authors who did not distinguish between *germinationis* and *petrei* must be ignored.

Opomyza petrei Mesnil

Figs. 1, 23, 24, 42

Opomyza petrei Mesnil, 1934, Rev. franç. Ent. 1: 202; Balachowsky and Mesnil, 1935, Ins. nuis. Plantes cult., p. 1029; Collin, 1945, Ent. Rec. 57: 14.

Male.—Length 3.7 to 4.1 mm. Very similar to that of *O. germinationis* but paler and less variable in colour, differing as follows: Head mostly yellow-brown. Thorax dull yellow, only slightly brownish, but with markings as in *germinationis*. Abdomen yellow-brown, with extreme lateral margins and with median stripe which tapers posteriorly, dark brown (as in Fig. 42); sternite eight brown posteriorly; tergite nine yellowish. Tergite nine (Fig. 23) with tooth-like process more distinctly separated from rest of sclerite, and with many more bristles along ventral margin. Cercus slightly angulate posteriorly, blunt apically, the apex (Fig. 24) with many short, strong black setulae.

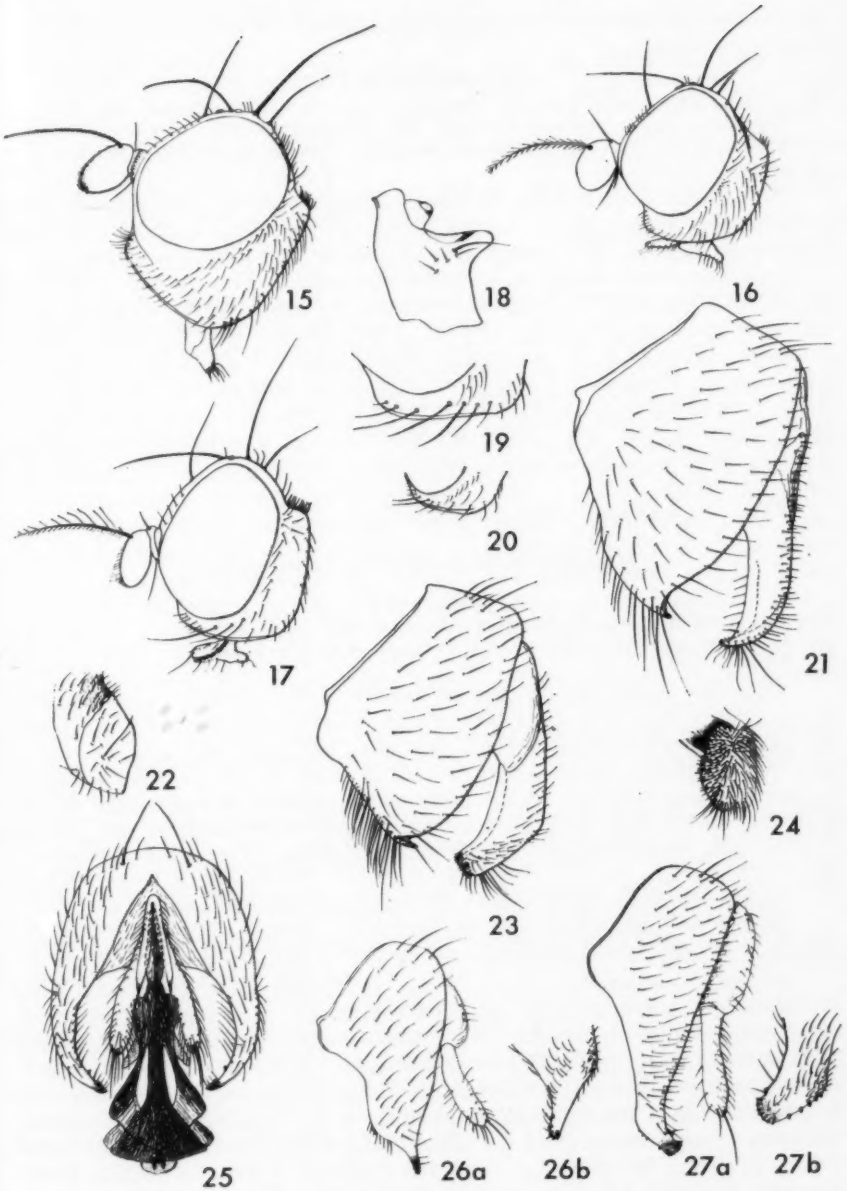
Female.—Length 3.7 to 4.1 mm. Very similar to male; abdomen (Fig. 42) only slightly variable in colour, yellow with brown median stripe which is broad anteriorly but tapers strongly posteriorly, and with dark brown lateral stripe which is visible in dorsal view only on tergites five and six.

Distribution.—Southwestern British Columbia and Vancouver Island (obviously introduced); Europe.

Specimens examined.—13 ♂♂, 9 ♀♀, Cultus Lake (H. R. Foxlee), Milner (W. R. Mason, G. J. Spencer), Abbotsford (W. R. Mason), all on the mainland of B.C., and Qualicum Bay (R. Coyles), Qualicum (G. E. Shewell), Miracle Beach nr. Oyster River (J. R. McGillis), Duncan (G. E. Shewell), all on Vancouver Island [C.N.C., U.S.N.M., C.A.S., collection M. R. Wheeler]. The Cultus Lake specimens were collected in 1948, the others in 1953 and 1955; dates are from 11.VI to 12.VIII. 1 ♂, 1 ♀, Niewekoop, Holland [C.N.C., through the kindness of Dr. W. Hackman].

Type locality and type.—France. Location of type unknown to me.

Discussion.—Canadian and European specimens, including male terminalia, have been compared. *O. petrei* has been reared in France from *Anthoxanthum* (Balachowsky and Mesnil, 1935), and in England from *Holcus lanatus* L. and



Figs. 15-27. 15-17. Head. 15, *Opomyza germinationis* (L.). 16, *Anomalochaeta guttipennis* (Zett.). 17, *Geomyza balachowskyi* Mesnil. 18, Left pteropleuron, *G. lurida* (Lw.). 19-20. Left cheek. 19, *G. lurida* (Lw.). 20, *G. coquilletti* Hendel. 21, 23. Tergite nine and cercus, lateral. 21, *O. germinationis* (L.). 23, *O. petrei* Mesnil. 22, 24. Apex of cercus, anterior. 22, *O. germinationis* (L.). 24, *O. petrei* Mesnil. 25. Tergite nine, aedeagus and cerci, posterior, *G. balachowskyi* Mesnil. 26-27. Tergite nine and cercus, lateral (a), and inner surface of surstylar process enlarged (b). 26, *G. balachowskyi* Mesnil, Fakenham, Norfolk, England. 27, *G. combinata* of Hackman (1959), Surrey, England.

Anthoxanthum odoratum L. (Nye, 1958). These authors have described and figured the larva.

Anomalochaeta Frey

Anomalochaeta Frey, 1921, Acta Soc. Fauna Flora fenn. 48 (3): 25; Czerny, 1928, Flieg. pal. Reg. 54c: 2; Hackman, 1958, Not. ent., Helsingf. 38: 115.

Type species: *Opomyza guttipennis* Zetterstedt 1838 by original designation and by monotypy.

Moderately slender, brownish-black, slightly pollinose; wing greyish-brown with rounded hyaline spots. Length 2.6 to 3.3 mm. Head as in Fig. 16; cheek moderately narrow, with a single row of weak subequal peristomal hairs; postverticals short, weak, divergent; arista short-pubescent. One presutural and three postsutural dorsocentrals. Scutellum with a few hairs above, with two weak sub-basal and two strong apical bristles. Pteropleuron with a few hairs, without a bristle. Wing (Fig. 2) moderately broad, alula and anal lobe present; anal vein present, incomplete. Male with tergite six present as a narrow, free, dorsal sclerite between tergite five and sternite eight (the latter dorsal in position). Tergite nine (Fig. 40) small, lower margin rounded, without distinct surstylar process. Cercus weakly sclerotized. Female terminalia as described above for family.

Only one species of the genus is known.

Anomalochaeta guttipennis (Zetterstedt)

Figs. 2, 16, 40

Opomyza guttipennis Zetterstedt, 1838, Ins. Lapp. 3: 762.

Anomalochaeta guttipennis, Czerny, 1928, Flieg. pal. Reg. 52c: 2; Hackman, 1958, Not. ent., Helsingf. 38: 115.

Male.—Brownish-black except as follows: front medially and anteriorly orange-brown; face and upper half of cheeks yellowish-white; antenna mostly orange-brown; palpus yellow-orange; fore coxa, basal third or less of fore femur, basal half of mid and hind femora, and all of tibiae and tarsi mostly yellowish-brown to orange-brown. Thorax moderately pollinose, abdomen very slightly pollinose. Wing (Fig. 2) greyish-brown, with about ten more or less rounded hyaline spots which vary slightly in size and shape. Terminalia as described above.

Female.—Very similar to male. Terminalia as described above.

Distribution.—Hudsonian and Canadian zones of North America (Alaska to Ontario); northern Europe and Siberia.

Specimens examined.—10 ♂♂, 18 ♀♀ from ALASKA: Lower Yukon River (C. O. Berg), Fairbanks (J. M. Aldrich), Matanuska (J. C. Chamberlin), 30 mi. north of Anchorage (R. I. Sailer), King Salmon on Naknek River (W. R. Mason, J. B. Hartley); NORTHWEST TERRITORIES: Aklavik (E. F. Cashman), Yellowknife (J. G. Chillcott); ALBERTA: Edmonton (F. S. Carr); SASKATCHEWAN: Christopher L. (A. R. Brooks); MANITOBA: Warkworth Creek nr. Churchill (J. G. Chillcott); ONTARIO: Moose Factory (E. J. Leroux) [C.N.C., U.S.N.M., coll. M. R. Wheeler, coll. J. E. Collin, Newmarket]. Dates from 8.IV to 26.VIII. Also 1 ♀, Pelkosenniemi, FINLAND: 1 ♂, Sonostroff [Kola Peninsula, RUSSIA] [U.Z.M.H.].

Type locality and types.—Southern Lapland, Sweden. Types of both sexes presumably in Univ. Zool. Mus., Lund.

Discussion.—I have compared North American and European specimens, including the male terminalia. There is slight variation in specimens from both areas in the number, size and arrangement of the pale wing spots but no indication of any geographic or specific differences.

Geomyza Fallén

Geomyza Fallén, 1810, Nov. Dipt. Disp. Meth., p. 18; Fallén, 1823, Dipt. Suec. Geomyz., p. 2; Melander, 1913, J. N.Y. ent. Soc. 21: 284; Czerny, 1928, Flieg. pal. Reg. 54c: 7; Curran, 1934, Fam. Gen. N. A. Dipt., p. 331; Mesnil, 1934, Rev. franç. Ent. 1: 194; Collin, 1945, Ent. Rec. 57: 14; Hackman, 1958, Not. ent., Helsingf. 38: 118.

Type species: *Musca combinata* Linnaeus 1767 by monotypy.

Balioptera Loew, 1864, Berl. ent. Z. 8: 347.

Type species: *Musca combinata* Linnaeus 1767, the first of seven originally included species, by designation of Coquillett (1910).

Mutiloptera Coquillett, 1908, Proc. ent. Soc. Wash. 9: 147; Melander, 1913, J. N.Y. ent. Soc. 9: 285; Hendel, 1917, Dtsch. ent. Z., p. 39; Curran, 1934, Fam. Gen. N. A. Dipt., p. 331.

Type species: *Mutiloptera apicalis* Coquillett 1908 (=*Mutiloptera coquilletti* Hendel 1917) by original designation and by monotypy.

Geomyzella Enderlein, 1936, Tierwelt Mitteleur. 16 (3): 167.

Type species: *Geomyza angustipennis* Zetterstedt 1847 by monotypy.

Slender to very slender, yellowish, reddish or blackish, shining; wing (Figs. 3-14) with apical spot and usually with clouded crossveins. Length 2.0 mm. to 3.9 mm. Head as in Fig. 17; cheek narrow, with a single row of peristomal hairs one or more of which, in Nearctic species, are enlarged and bristle-like; postverticals absent; arista, in Nearctic species, long-haired above, short-haired below. One presutural and two or three postsutural dorsocentrals. Scutellum without hairs above, with two weak sub-basal and two strong apical bristles. Pteropleuron with a few hairs, rarely with a weak bristle. Wing (Figs. 3-14) moderately broad to very narrow, sometimes with posterior margin straight or slightly concave and with cells of posterior half of wing very narrow; alula, anal lobe and anal vein absent. Male with tergite six absent; tergite nine (Figs. 25-39) moderately large, with an elongate, usually slender, tapering surstylar process which is curved mediad at its apex and has its apical portion armed with very short, blunt spines; cercus elongate, slender, weakly sclerotized, without distinctive vestiture. Female terminalia as described above for family.

Discussion.–Several species, particularly *Geomyza apicalis* (Mg.) and *G. coquilletti* (Hend.), show considerable variation in width and shape of wings and in presence or length of the first postsutural dorsocentral. This variation has apparently led to some specific synonymy – *G. apicalis* (Mg.) and *G. hendeli* Czerny are tentatively synonymized by Hackman (1958). It also indicates that the retention of *Mutiloptera* Coquillett and of *Geomyzella* Enderlein as genera or even as subgenera is unnecessary.

About 18 species of *Geomyza* have been recorded from the Palaearctic Region, mostly from Europe, but the identity of many of these is uncertain. Mesnil (1934), Collin (1945) and Hackman (1958) have provided a valuable basis for a revision, but until adequate series are available and the male genitalia, particularly of the types, have been studied, confusion and doubt will remain. Even then, as in North America, females of some species may remain indistinguishable.

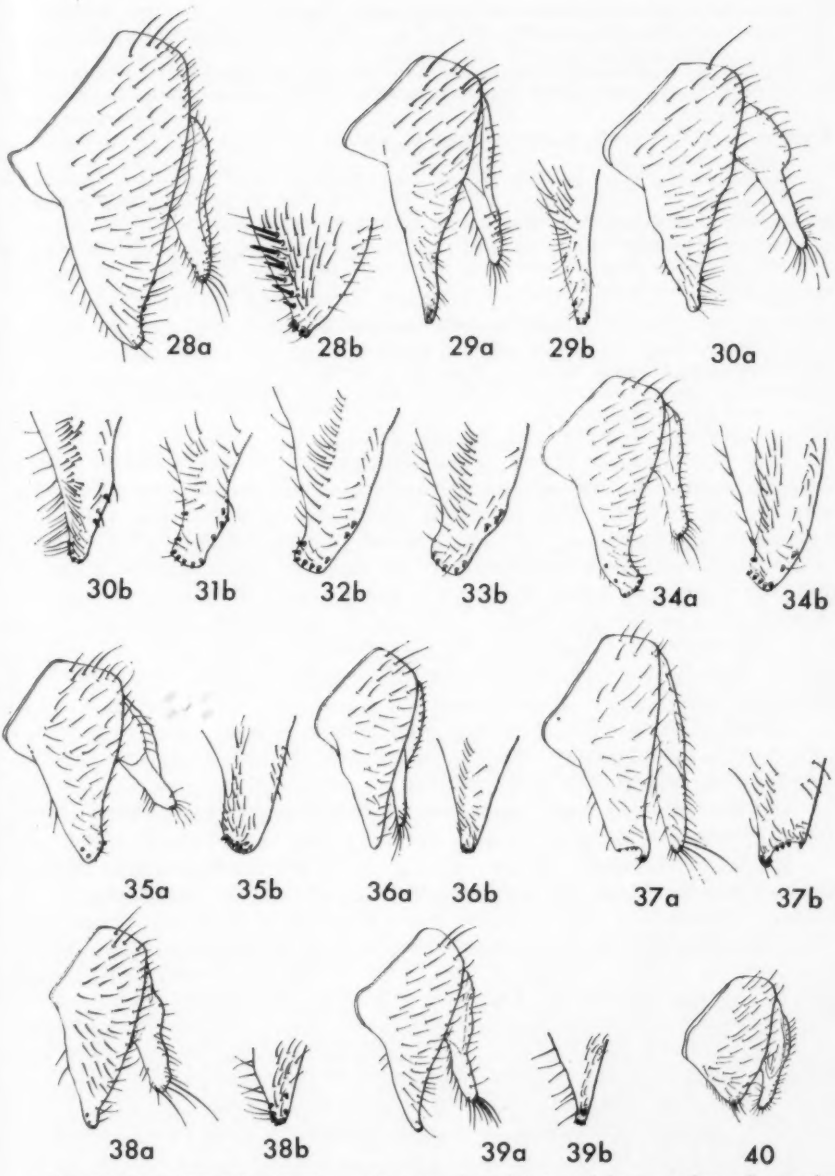
One species, *G. balachowskyi* Mesnil, obviously has been introduced into North America from the Palaearctic Region. Two other common European species may enter in the future. One of these, *G. combinata* L. of Hackman (1958) (see below under *balachowskyi* for discussion of nomenclature) is distinguishable from *balachowskyi* only by the form of the surstylar process (Figs. 26, 27). The other, *G. tripunctata* Fall., has a distinct pteropleural bristle (as has *lurida* Lw. among Nearctic species) but has much larger crossvein clouds

than *lurida* or any other Nearctic species. Mesnil (1934) and Balachowsky and Mesnil (1935) have figured the whole fly, the surstylar process, and other details. Mesnil (1934) treated as *combinata* L. a species apparently very similar to *tripunctata;* it should be watched for among supposed *tripunctata.*

Three Nearctic species, *apicalis* (Mg.), *coquilletti* (Hend.) and *velata* n. sp., have the wings reduced to a variable extent (Figs. 9-14). Individuals of these species occur on the ground among the grasses in which they presumably breed; they flit rapidly at most a few inches when disturbed, but are apparently incapable of sustained flight. I have myself taken most of the available North American specimens of these species by searching on the ground and collecting with an aspirator, and have taken *apicalis* (Mg.) in Europe in the same way. Despite extensive sweeping of grasses I have not taken a specimen of these species with a net, although I have collected numbers of *balachowskyi* Mesnil, of *monticola* n. sp. and of several European species by sweeping.

Key to North American species of *Geomyza*

1. Pteropleuron without a bristle among the hairs; at most two peristomal hairs strong and bristlelike; male, surstylar process without strong black bristles on median surface 2
   Pteropleuron with a weak but distinct bristle among the hairs (Fig. 18); three or four peristomal hairs strong and bristlelike (Fig. 19); male, surstylar process with long, strong black bristles on median surface (Fig. 28) ..... *lurida* (Loew)
2. Cloud at apex of vein M_{1+2} present and connected at least faintly with apical wing spot 3
   Cloud at apex of vein M_{1+2} absent or not connected with apical spot 7
3. Thorax usually with brownish markings on pleura, often mostly or entirely brown or blackish; tergite three and following tergites, and often tergites one and two, dark brown to black; cloud of posterior crossvein usually faint (Figs. 6, 9-14); wing often narrow and with posterior margin almost straight or slightly concave (Figs. 9-14); male, surstylar process as in Figs. 34, 37-39 4
   Thorax entirely yellow or reddish yellow; tergite one and base of tergite two yellow, base of tergite three often yellow; cloud of posterior crossvein moderately broad, distinct; wing moderately broad, convex posteriorly (Fig. 3); male, surstylar process with apex suddenly narrowed, acute and directed slightly caudad (Fig. 26) ..... *balachowskyi* Mesnil
4. Posterior crossvein approximately twice as long as anterior crossvein; cell R_{4+5} not conspicuously broadened at level of posterior crossvein (Figs. 6, 9-11); wing broad to very narrow 5
   Posterior crossvein subequal to anterior crossvein; cell R_{4+5} conspicuously broadened at level of posterior crossvein; wing narrow to very narrow (Figs. 12-14) ..... *coquilletti* (Hendel)
5. Wing (Figs. 9-11) narrow to very narrow, its posterior margin almost straight or only slightly convex 6
   Wing (Fig. 6) broad, its posterior margin strongly convex; male, surstylar process as in Fig. 34 ..... *monticola* n. sp.
6. Wing (Fig. 9) narrow, relatively uniform in width, rounded apically; ocellar triangle yellow, scarcely delimited from rest of front; male, surstylar process (Fig. 37) with strongly narrowed, hooked apex ..... *velata* n. sp.
   Wing (Figs. 10, 11) narrow to very narrow, variable in width, usually pointed apically; ocellar triangle dark brown, plainly delimited from rest of front; male, surstylar process (Fig. 38) tapering regularly to a bluntly rounded apex ..... *apicalis* (Meigen)
7. Thorax always with brown or blackish markings, sometimes entirely dark; wing (Figs. 5, 7, 8) with crossvein clouds faint or absent and with apical spot small; male, surstylar process (Figs. 29, 30, 35, 36) variable but not suddenly and strongly narrowed just before apex 8
   Thorax yellow or reddish yellow; wing (Fig. 3) with crossvein clouds distinct and with apical spot large and distinct; male, surstylar process (Fig. 26) strongly narrowed just before apex ..... *balachowskyi* Mesnil



Figs. 28-40. 28-39. Tergite nine and cercus, lateral (a), and inner surface of surstylar process enlarged (b). 28, *G. lurida* (Lw.), Hatzic Lake, B.C. 29, *G. monostigma* Melander, Headwaters Pescadero Cr., San Mateo Co., Calif. 30, *G. vespertina* n. sp., holotype, Arboretum, Arcadia, Calif. 31, *G. vespertina* n. sp., Los Angeles, Calif. 32, *G. vespertina* n. sp., Lakeside, Tahoe, Calif. 33, *G. vespertina* n. sp., Farmington, Utah. 34, *G. monticola* n. sp., paratype, Elkwater, Alta. 35, *G. parvistigma* n. sp., holotype, Robson, B.C. 36, *G. dolomata*, holotype, Cameron Pass, Colo. 37, *G. velata* n. sp., paratype, Sturgis, Sask. 38, *G. apicalis* (Mg.), Kentville, N.S. 39, *G. coquilletti* (Hend.), St. Victor, Sask. 40. Tergite nine and cercus, lateral, *A. guttipennis* (Zett.).

8. (Males only) Anterior crossvein unclouded, posterior crossvein at most very slightly clouded, apical wing spot very small (Figs. 5, 8); surstylar process (Figs. 29, 35, 36) without anterior preapical prominence 9
(Males only) Crossveins slightly but distinctly clouded, apical spot of moderate size (Fig. 7); surstylar process (Figs. 30-33) with distinct anterior preapical prominence ..... *vespertina* n. sp.
9. Surstylar process (Figs. 35, 36) of moderate length, with five or more short, black, blunt spines at apex 10
Surstylar process (Fig. 29) long and slender, with four short, black, blunt spines at apex ..... *monostigma* Melander
10. Surstylar process (Fig. 36) rather slender, with five or six short, black, blunt apical spines in a single row ..... *dolomata* n. sp
Surstylar process (Fig. 35) stout, with about ten short, black, blunt apical spines in a partial double row ..... *parvistigma* n. sp.

Geomyza balachowskyi Mesnil

Figs. 3, 17, 25, 26

?Musca combinata Linnaeus, 1767, Syst. Nat., ed. 12, p. 997.
Geomyza balachowskyi Mesnil, 1934, Rev. franç. Ent. 1: 197; Balachowsky and Mesnil, 1935, Ins. nuis. Plantes cult., p. 1043.
Geomyza combinata, Collin, 1945, Ent. Rec. 57: 15.

Male.—Length 2.6 to 3.0 mm. Head and legs yellow; thorax reddish-yellow; abdomen above with first segment or two reddish yellow and remainder black, below yellow to black. One peristomal hair strong, bristlelike (Fig. 17). First postsutural dorsocentral strong. Pteropleuron without bristle. Wing (Fig. 3) moderately broad, convex posteriorly; both crossveins distinctly clouded; apical spot rather large, its proximal margin almost perpendicular; apex of vein M_{1+2} clouded, the cloud usually faintly connected to apical spot. Surstylar process (Fig. 26a) strongly constricted, the slender apical portion directed slightly caudad; inner surface (Fig. 26b) with about three short spines at angle and with about six at apex.

Female.—Length 3.0 to 3.7 mm. Very similar to male. Abdomen usually yellow with reddish-brown incisures, sometimes blackish but always with at least anterior margins of tergites reddish.

Distribution.—East and west coasts of North America (obviously introduced); Europe.

Specimens examined.—52 ♂♂, 82 ♀♀ from BRITISH COLUMBIA: Massett, Queen Charlotte Is. (E. E. MacDougall); Cowichan Lake, Vancouver I. (R. Coyles); Mission City (W. R. Mason, Edith Mason, G. J. Spencer); Hatzic Lake (Spencer); MacGillivray Creek Game Reserve nr. Chilliwack (Spencer); Cultus Lake (H. R. Foxlee); Langford (D. Evans, J. W. E. Harris); Huntingdon (W. R. Mason); Abbotsford; WASHINGTON: Sears Lk., Ft. Lewis (P. H. Arnaud); Seattle; OREGON: Humbug Mt. State Park, Curry Co.; NOVA SCOTIA: Lockeport (J. R. Vockeroth); Smith's Cove (G. C. Steyskal); CONNECTICUT: Canaan (A. Stone). Dates from May to Sept. Specimens from Seattle taken in 1943, from Sears Lake in 1945, from B.C. in 1948 *ff.*, from Conn. in 1952, from N.S. in 1955 and 1958. In many collections. 5 ♂♂ from ENGLAND, GERMANY and AUSTRIA (C.N.C., U.S.N.M., C.A.S.).

Type locality and type.—France. Location of type unknown to me.

Discussion.—This species was treated by Collin (1945) as *Geomyza combinata* (Linnaeus) 1767. I would have followed him in the use of this name had not Hackman (1958) used the name *combinata* (L.) for another species (separable from *combinata*, Collin only by the male terminalia (Figs. 26, 27)) in the belief that his species was the same as Collin's. Mr. Collin has told me (in *litt.*) that his collection contains only *combinata*, Collin from Great Britain; Dr. Hackman

has said (in *litt.*) that his Finnish specimens are all *combinata*, Hackman. However, both species occur in England; in the C.N.C. are two males of *combinata*, Collin from Norfolk and Surrey, and two males of *combinata*, Hackman from Oxford and Surrey. All other European males I have examined have been of *combinata*, Collin.

Mesnil (1934) treated a third species as *combinata* (L.) and the terminalia figured by Czerny (1928) as those of *combinata* (L.) are apparently those of a fourth species. Until the identity of *combinata* (L.) is determined by examination of the type, or, if the type is lost or is an unidentifiable female, by examination of specimens from Upsala, Sweden, the name *combinata* should not be used.

Mesnil (1934) and Balachowsky and Mesnil (1935) record *G. balachowskyi* from two species of *Holcus;* the larvae are said to be very abundant and to cause considerable damage. The larva is described and figured in both these papers. The larva described and figured by Nye (1958) as that of *G. combinata* (L.) is probably that of *G. balachowskyi.*

Geomyza lurida (Loew)

Figs. 4, 18, 19, 28

Opomyza lurida Loew, 1864, Berl. ent. Z. 8: 98; Loew, 1864, Dipt. Amer. Sept. Ind., Cent 5: 260.

Balioptera lurida, Loew, 1864, Berl. ent. Z. 8: 356.

Geomyza lurida, Melander, 1913, J. N. Y. ent. Soc. 21: 288; Hackman, 1958, Not. ent., Helsingf. 38: 125.

Male.—Length 3.3 to 3.9 mm. Head orange yellow, upper half of postcranium brownish; thorax reddish-brown; legs yellow; abdomen brownish-black to black, the first segment and terminalia reddish-brown. Three peristomal hairs bristlelike, subequal (Fig. 19). First postsutural dorsocentral strong. Pteropleuron (Fig. 18) with a weak but distinct bristle. Wing (Fig. 4) broad, convex posteriorly; crossveins distinctly clouded; apical spot moderate, ending just beyond vein R_{4+5}, its proximal margin slightly sloping; apex of vein M_{1+2} very slightly clouded. Surstylar process (Fig. 28a) broad, tapering evenly to a blunt, very slightly curved, apex; inner surface (Fig. 28b) with a cluster of long, heavy, black spines near posterior margin, preapically with four short spines in a regular row.

Female.—Length 3.7 to 4.4 mm. Very similar to male; abdomen as dark as in male.

Distribution.—Southern Alaska south to southern California (west of Coast Ranges only).

Specimens examined.—15 ♂♂, 31 ♀♀ from ALASKA: Sitka (Sahlberg); Dall I.; Big Castle I. in Duncan Canal, Kupreanof I.; Falls Creek, Wrangel Narrows, Mitkof I.; BRITISH COLUMBIA: Moresby Camp, Queen Charlotte I. (E. E. MacDougall); Masset, Q.C.I. (MacDougall); Tlell, Q.C.I. (MacDougall); Juskatla, Q.C.I. (MacDougall); Bowser, Vancouver I. (J. R. McGillis); Victoria, V.I. (K. F. Auden); Hatzic Lake (W. R. Mason); Hatzic (Mason); Milner (Mason); Agassiz (H. H. Ross); WASHINGTON: Big Four Mt. (A. L. Melander); Carson (M. R. Wheeler); Seattle (H. G. Dyar); Mt. Constitution, Orcas I. (J. M. Aldrich); OREGON: Beaver Co., Newport (Aldrich); Warrenton (E. Gray); Astoria (Grey and Schuh); CALIFORNIA: Prairie Creek State Park, Humboldt Co. (Wheeler); Eureka (H. S. Barber); Headwaters Pescadero Cr., San Mateo Co. (P. H. Arnaud); Rosemead nr. Pasadena (Wheeler). Dates from Feb. to Oct. in Calif., May to Sept. in Canada and Alaska. In C.N.C., U.S.N.M., M.C.Z., C.A.S., collections of M. R. Wheeler, G. Steyskal, C. W. Sabrosky, J. E. Collin.

Type locality and types.—Sitka, Alaska. Hackman (1958) figured the terminalia of a male syntype in the Frey coll., U.Z.M.H.; I have examined a female syntype in M.C.Z.

Discussion.—This species is the only native North American fly (apart from littoral species) known to me to occur only on the Pacific side of the Coast Ranges of the Cordillera. In the Frazer and Columbia River valleys it occurs up to 100 mi. inland, but does not appear to cross the mountains. This distribution pattern is reported by Van Dyke (1919) to be very common in Coleoptera.

Geomyza monostigma Melander

Figs. 5, 29

Geomyza monostigma Melander, 1913, J. N. Y. ent. Soc. 21: 288.

Male.—Length 3.4 mm. Head dark yellow with upper two-thirds or more of occiput and upper half of front reddish-brown. Thorax brownish-black, humeri and scutellum reddish-brown, pleura with some reddish areas. Legs dark yellow, hind femur brown preapically on dorsal and posterior surfaces, hind tibia brownish on basal and apical thirds. Abdomen entirely dark brownish-black. One peristomal hair strong, bristlelike; one or two others moderately strong but much shorter. First postsutural dorsocentral strong. Pteropleuron without bristle. Wing (Fig. 5) broad, convex posteriorly; anterior crossvein unclouded, posterior crossvein with a very faint, narrow cloud; apical spot small, ending just beyond vein R_{4+5}, its proximal margin almost perpendicular; vein M_{3+4} without apical cloud. Surstylar process (Fig. 29a) very long, slender, tapering almost regularly to a narrow, truncate apex; inner surface (Fig. 29b) with four short marginal spines near apex.

Female.—Length 3.7 mm. Very similar to male.

Distribution.—West coast of U.S.A. from Washington to central California.

Specimens examined.—1 ♂, 2 ♀ ♀ from WASHINGTON: Seattle (1 ♀ syntype, in coll. A. L. Melander); CALIFORNIA: Headwaters Pescadero Creek, San Mateo Co. (1 ♂, 1 ♀, Oct. 19, P. H. Arnaud, in coll. G. Steyskal).

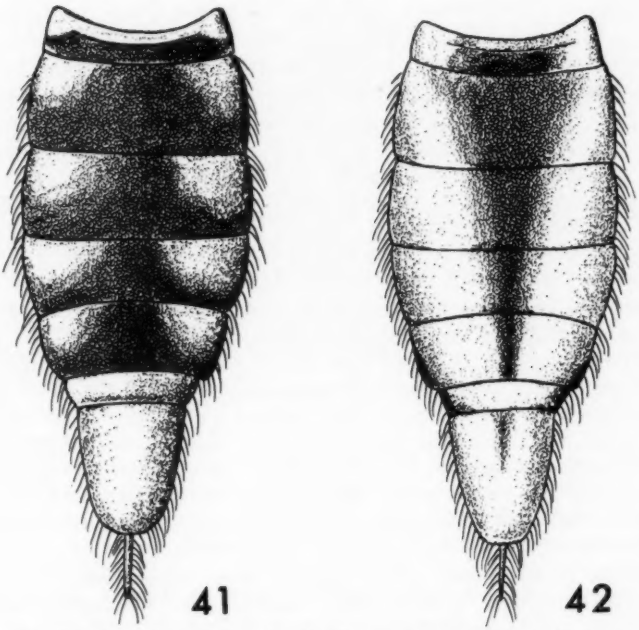
Type localities and types.—Seattle, Wash.; Stanford Univ. (Palo Alto), Calif. One female syntype from each locality in collection of A. L. Melander; I have examined the syntype from Seattle.

Discussion.—The pair from San Mateo Co. agree well with the Seattle syntype and are probably conspecific. The female of *monostigma* is separable only with difficulty from those of *vespertina* n. sp., *parvistigma* n. sp. and probably *dolomata* n. sp., but seems to be slightly larger than any of these.

Geomyza monticola, new species

Figs. 6, 34

Male.—Length 2.4 to 3.0 mm. Colour as in *monostigma* Melander except that hind femur usually has a broad, preapical brownish ring and hind tibia is usually entirely brown. One peristomal hair strong, bristlelike. First postsutural dorsocentral moderately strong. Pteropleuron without bristle. Wing (Fig. 6) moderately broad, convex posteriorly; anterior crossvein with at most a very faint cloud, posterior crossvein with a faint, narrow cloud; apical spot moderately large, extending faintly but distinctly beyond vein M_{3+4}, its proximal margin almost perpendicular. Surstylar process (Fig. 34a) stout, its apex truncate and curved slightly caudad; inner surface (Fig. 34b) with two anterior and one posterior short spines well before apex and a regular row of about five short spines just before apex.



Figs. 41-42. Female abdomen, dorsal. 41, *Opomyza germinationis* (L.). 42, *O. petrei* Mesnil.

Female.—Very similar to male, mid femur sometimes brownish preapically and hind femur sometimes a little darker.

Distribution.—Southeastern Alberta and southwestern Saskatchewan.

Holotype.— ♂, Elkwater, Alberta, (49°42'N, 110°16'W), June 2, 1955 (J. R. Vockeroth). Type No. 7370, Canadian National Collection.

Paratypes.—13 ♂♂, 12 ♀♀, same data as holotype; 1 ♂, 1 ♀, Onefour, Alta., June 4, 1955 (Vockeroth); 1 ♂, 1 ♀, Maple Creek, Saskatchewan, May 28, 1955 (Vockeroth); 1 ♀, Cypress Hills, Sask., May 26, 1955 (Vockeroth). In C.N.C., U.S.N.M., U.Z.M.H., collections of M. R. Wheeler and J. E. Collin.

Discussion.—See below under *G. vespertina* n. sp.

***Geomyza vespertina*, new species**

Figs. 7, 30-33

Male.—Length 3.0 mm. Colour of head, thorax, legs and abdomen as in *monostigma* Melander. One peristomal hair strong, bristlelike. First postsutural dorsocentral moderately strong. Pteropleuron without bristle. Wing (Fig. 7) moderately broad, convex posteriorly; crossveins each with a narrow but distinct cloud; apical spot small, ending just behind vein R_{4+5}, its proximal margin almost perpendicular; apex of vein M_{1+2} at most very faintly clouded. Surstylar process (Figs. 30-33) of moderate length, tapering rather regularly to a rounded subtruncate apex of very varying width, with a slight but distinct anterior preapical prominence and with apex directed slightly caudad, with two to four short, blunt, black spines near the anterior prominence and with four to seven spines at apex and occasionally along posterior margin.

Female not definitely known (see discussion below).

Distribution.—Southern California; perhaps widespread in western U.S.A.

Holotype.—♂, Arboretum, Arcadia, California, Nov. 2, 1949 (M. R. Wheeler). Type No. 7371, Canadian National Collection.

Paratypes.—1 ♂, same data as holotype, but Nov. 15, 1949; 1 ♂, Arcadia, California, April 28, 1950 (M. R. Wheeler). In C.N.C. and collection of M. R. Wheeler.

Other specimens examined.—7 ♂♂, 3 ♀♀ from CALIFORNIA: Carmel (M. Cazier; 1 ♂; in A.M.N.H.); Lakeside, Tahoe (J. M. Aldrich; 1 ♂, 2 ♀; in U.S.N.M.); Kern River (M. R. Wheeler; 1 ♂; coll. Wheeler); Los Angeles (M. C. Van Duzee; 1 ♂; M.C.Z.); UTAH: Far West (W. L. Thomas; 1 ♂; A.M.N.H.); Farmington (G. F. Knowlton; 1 ♂, 1 ♀; U.S.N.M.); Provo (G. F. Knowlton; 1 ♂; U.S.N.M.). Dates from May to Sept.

Discussion.—The specimens tentatively assigned to this species show great variation in the shape of the surstylar process. In the holotype and paratypes the apex is very narrow (Fig. 30b); in the specimens from Los Angeles (very near the type locality) the apex is broader (Fig. 31b); in the other specimens listed above the apex is broader still but the shape of the apical portion is slightly variable (Figs. 32b, 33b). G. *monticola* n. sp. differs from *vespertina* in the extent of the apical wing spot, but the shape of the surstylar process falls within the range of variation shown by the seven males tentatively assigned to *vespertina*. It is possible that only one species is involved, or that these seven males are conspecific with *monticola* rather than with *vespertina*.

The three females listed above agree with the associated males in colour, size and wing markings. Eleven other females, from Washington, Idaho, California, Nevada and Chapingo, Mex. (all in U.S.N.M.) are before me; the wing markings and size are sufficiently variable that they cannot at present be assigned definitely to *vespertina* rather than to *monostigma* Melander, *dolomata* n. sp. or *parvistigma* n. sp.

Geomyza parvistigma, new species

Figs. 8, 35

Male.—Length 2.8 mm. Colour of head, thorax, legs and abdomen as in *monostigma* Melander. One peristomal hair strong, bristlelike. First postsutural dorsocentral very short and weak. Pteropleuron without bristle. Wing (Fig. 8) moderately broad, convex posteriorly; crossveins unclouded; apical spot very small, extending very little past vein R_{4+5}, its proximal margin almost perpendicular; vein M_{1+2} with apex unclouded. Surstylar process (Fig. 35a) short, moderately stout, evenly tapering; inner surface (Fig. 35b) apically with one larger short spine and an irregular double row of about nine smaller short spines.

Female.—Length 3.0 mm. Very similar to male, hind femur and tibia sometimes a little darker.

Distribution.—Southern British Columbia.

Holotype.—♂, Robson, British Columbia, Sept. 19, 1948 (H. R. Foxlee). Type No. 7372, Canadian National Collection.

Paratypes.—2 ♀♀, Robson, B.C., July 30, 1947 and Aug. 4, 1952 (H. R. Foxlee). In C.N.C.

Discussion.—The female can probably not be distinguished with certainty from those of *monostigma* Melander and *dolomata* n. sp.

Geomyza dolomata, new species

Fig. 36

Male.—Length 3.0 mm. Colour and wing markings as in *G. monostigma* Melander (Fig. 5) except that costal cells are paler apically and hind legs have

the brownish markings less distinct. One peristomal hair strong and bristlelike, the others weak. First postsutural dorsocentral very short and weak, about one-fifth as long as second (probably variable). Pteropleuron without bristle. Surstylar process (Fig. 36a) rather slender, its inner surface (Fig. 36b) with five or six short, black, blunt spines in a single regular apical row.

Female not definitely known.

Distribution.—Utah, Colorado.

Holotype.—♂, Cameron Pass, Colorado, 11,500 ft., Aug. 19-22, 1940 (C. W. Sabrosky). In U.S.N.M.

Paratype.—♂, Vernal Canyon, Uinta Mts., Utah, Aug. 18, 1940 (D. G. Hall). In U.S.N.M.

Discussion.—The female can probably not be distinguished with certainty from those of *monostigma* Melander and *parvistigma* n. sp.

Geomyza velata, new species

Figs. 9, 37

Male.—Length 2.8 mm. Head yellow with upper half of front reddish-yellow and upper half of postcranium brownish; ocellar triangle not sharply delimited. Thorax reddish-yellow to reddish-brown; postscutellum and irregular areas on pleura brownish. Legs yellow, hind femur sometimes with broad preapical ring brownish. Abdomen with tergite one and extreme base of tergite two reddish-yellow, otherwise brownish-black. One peristomal hair moderately strong, bristlelike. First postsutural dorsocentral moderately strong, about half as long as the second. Pteropleuron without bristle. Wing (Fig. 9) rather narrow, apparently constant in shape, with posterior margin almost straight and apex rounded; anterior crossvein with faint cloud, posterior crossvein with distinct moderately large, cloud; posterior crossvein almost twice as long as anterior; cell R_{4+5} not conspicuously broadened at level of posterior crossvein; apical spot large, covering whole apex of wing, a little fainter beyond middle of cell R_{4+5}. Surstylar process (Fig. 37a) broad, evenly tapering, with a slender, slightly curved hook at posteroventral angle; inner surface (Fig. 37b) with a single row of about eight irregularly spaced short spines along apical margin.

Female.—Length 3.0 to 3.3 mm. Similar to male but usually with peristomal hairs stronger.

Distribution.—Central Alberta, central Saskatchewan.

Holotype.—♂, Sturgis, Sask. (51°56′N, 102°32′W), July 1, 1955 (J. R. Vockeroth). Type No. 7373, Canadian National Collection.

Paratypes.—3 ♂♂, 6 ♀♀, same data as holotype; 1 ♂, McMurray, Alta., August 8, 1953 (G. E. Ball). In C.N.C., U.S.N.M.

Discussion.—The width and shape of the wing in *velata* varies much less than in *apicalis* (Meigen) and *coquilletti* (Hendel), the other two virtually flightless species. The series from Sturgis was collected on dry ground among sparse, rather coarse grass, on a lot which had been burned over the previous year.

Geomyza apicalis (Meigen)

Figs. 10, 11, 38

Opomyza apicalis Meigen, 1830, Syst. Beschr. 6: 109.
Balioptera apicalis, Loew, 1864, Berl. ent. Z. 8: 353.
Mutiloptera apicalis, Hendel, 1917, Dtsch. ent. Z., p. 39.
Geomyza apicalis, Czerny, 1928, Flieg. pal. Reg. 54c: 9; Collin, 1945, Ent. Rec. 57: 15; Hackman, 1958, Not. ent., Helsingf. 38: 119.

Male.–Length 2.0 to 3.0 mm. Head yellow, front sometimes reddish yellow; ocellar triangle and orbital plates (bearing vertical and frontal bristles) dark brown, shining, clearly delimited from the paler and less shining frontal vitta; upper half or more of postcranium dark brown. Thorax yellow-brown to dark brown, lower half of pleura a little paler. Legs yellow, most of apical half of mid femur sometimes brownish, apical half of hind femur and most of hind tibia usually brown. Abdomen black, tergite one and extreme base of tergite two yellow to yellow-brown. One peristomal hair strong, bristlelike. First postsutural dorsocentral at most half as long as second, usually much shorter, rarely completely absent. Pteropleuron without bristle. Wing (Figs. 10, 11) slightly variable in size and width, narrow, usually at least slightly pointed, posterior margin slightly convex to straight; anterior crossvein usually with a faint cloud, sometimes unclouded; posterior crossvein with a small but distinct cloud; posterior crossvein almost twice as long as anterior; cell R_{4+5} not conspicuously broadened at level of posterior crossvein; apical spot covering whole apex of wing, almost always fainter beyond middle of cell R_{4+5}. Surstylar process (Fig. 38a) moderately stout with rounded apex, curved very slightly caudad apically; inner surface (Fig. 38b) with two moderately strong hairs, with two short spines near anterior margin and a fairly regular row of about six short spines at apex and along apical part of posterior margin.

Female.–Length 2.6 to 3.3 mm. Similar to male; front darker so that ocellar triangle and orbital plates are much less clearly delimited; third antennal segment sometimes brownish apically.

Distribution.–Southern Ontario, Nova Scotia, Europe.

Specimens examined.–25 ♂♂, 31 ♀♀ from ONTARIO: Simcoe (J. R. Vockeroth); Marmora (Vockeroth); Ottawa (Vockeroth, J. F. McAlpine, H. F. Howden); Black Rapids nr. Ottawa (Vockeroth); NOVA SCOTIA: Kentville; Lockeport (Vockeroth). 5 ♂♂, 5 ♀♀ from ENGLAND: Dewsbury, Yorkshire (Vockeroth; 1 ♂); AUSTRIA: Igls, Tirol, 950 m. (Vockeroth; 4 ♂♂, 5 ♀♀). Dates from June to Nov. In C.N.C., U.S.N.M., C.A.S., U.Z.M.H. and collections of W. R. Wheeler, A. L. Melander and J. E. Collin.

Type locality and types.–Europe (probably Austria). Types in Winthem Collection in Natural History Museum, Vienna (Becker, 1902, p. 307).

Discussion.–I have compared North American and European specimens (including male terminalia) and can find no difference. Approximately the same amount of variation in size, wing shape and development of the first postsutural dorsocentral occurs in both groups of specimens.

The species is presumably native in North America; its apparent absence from the western two-thirds of the continent is probably due to lack of proper collecting. If it is introduced it is strange that it has spread so far with such limited powers of locomotion; the three obviously introduced species of the family, *G. balachowskyi* Mesnil and the two species of *Opomyza*, all with normal wings, have apparently scarcely spread from the Atlantic and/or Pacific coasts.

The species occurs on dry ground (roadsides, overgrown fields, etc.) among a variety of grasses.

Geomyza coquilletti (Hendel), new combination

Figs. 12-14, 20, 39

Mutiloptera apicalis Coquillett, 1908, Proc. ent. Soc. Wash. 9: 148; Melander, 1913, J. N. Y. Ent. Soc. 9: 292.

Mutiloptera coquilletti Hendel, 1917, Dtsch. ent. Z., p. 39 (n. n. for *apicalis* Coquillett).

Male.–Length 2.0 to 2.8 mm. Colour similar to that of *apicalis* Meigen, but front brownish, ocellar triangle and orbital plates less shining and less clearly

delimited; apical half or less of third antennal segment usually slightly brownish; mid and hind femora yellow, rarely slightly darkened on apical half; hind tibia with extreme base and apical third yellow, otherwise brownish. Peristomal hairs (Fig. 20) weak, two slightly stronger than the others, subequal, somewhat bristlelike. First postsutural dorsocentral usually completely absent, rarely present but very short, very rarely almost half as long as the second postsutural dorsocentral. Pteropleuron without bristle. Wing (Figs. 12, 13) very variable in size and shape, narrow to very narrow, pointed, posterior margin almost straight to slightly but distinctly concave; anterior crossvein sometimes duplicated, unclouded; posterior crossvein very slightly clouded; crossveins subequal in length; cell R_{4+5} conspicuously broadened at level of posterior crossvein; apical spot large, covering entire apex of wing. Surstylar process (Fig. 39a) slightly more slender than in *apicalis*, evenly tapering, apex subtruncate and curved slightly caudad; inner surface (Fig. 39b) with very weak hairs and with a row of about four short, black, blunt spines at apex.

Female.—Length 2.0 to 3.3 mm. Very similar to male; front more uniformly brownish and a little darker; wing very variable, usually a little broader than in male (Fig. 14).

Distribution.—Southern Alberta, southern Saskatchewan, North Dakota, South Dakota, Michigan.

Specimens examined.—37 ♂ ♂, 39 ♀ ♀ from ALBERTA: Banff (E. H. Strickland; 1 ♀); SASKATCHEWAN: St. Victor (J. R. Vockeroth; 36 ♂ ♂, 34 ♀ ♀); Assiniboia (Vockeroth; 1 ♂); NORTH DAKOTA: Tower City (G. I. Reeves; 2 ♀ ♀); SOUTH DAKOTA: Elk Point (C. N. Ainslie; 1 ♀); MICHIGAN: Detroit (G. C. Steyskal; 1 ♀). Dates from May to August. In C.N.C., U.S.N.M., U.Z.M.H., collections of G. C. Steyskal, M. R. Wheeler, A. L. Melander and J. E. Collin.

Type locality and types.—Tower City, N.D. I have examined two syntype females in the U.S.N.M.; that bearing the U.S.N.M. holotype label is hereby designated as lectotype.

Discussion.—Hendel (1917) treated *Mutiloptera* as a genus distinct from *Geomyza;* he transferred to it *Geomyza apicalis* (Meigen), and proposed *coquilletti* as a new name for *Mutiloptera apicalis* Coquillett.

The three specimens whose wings are shown in Figs. 12-14 are part of a series of 36 ♂ ♀ and 34 ♀ ♀ collected at one time on a few square feet of dry ground among short, native, prairie grasses. This series shows almost as great a variation in wing shape as was observed among all the material examined, although a few specimens from other localities had the wing slightly more curved. The specimen from Elk Point, N.D. was reared from *Elymus.*

The only other species with the wings sometimes as reduced as those of *coquilletti* is *apicalis* (Meigen); it differs from *coquilletti* in wing venation, in the shape of the surstylar process, in having only one bristlelike peristomal hair and in having a more sharply delimited frontal triangle.

Summary

Thirteen species of three genera of Opomyzidae are recorded from North America. Three of the species are obviously introduced from the Palaearctic Region. The genera *Opomyza* and *Anomalochaeta* are definitely recorded from North America for the first time. Five species, all of *Geomyza,* are described as new. The known larvae feed in grass stems; available host records are summarized.

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Effect of Adaptation on Stimulation of Flight in *Aedes aegypti* (L.) in a Changing Environment[1]

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Introduction

In subarctic Canada conventional methods of correlation and regression analyses were inadequate in relating periodicities in mosquito flight to fluctuating physical environments (Haufe, 1958). The periodicity for individual species shifted in relation to sidereal time. In addition to a random component in the variation, a gradual shift was associated with the advance of the season for consecutive cycles of activity. For the most abundant species it appeared as older individuals constituted an increasing proportion of the natural populations. The relative variations in absolute values of light and hygrothermal conditions identified with 24-hour flight periodicities were inconsistent with seasonal varia-

[1]This work was done in the Imperial College of Science and Technology as part of a thesis submitted for the Ph.D. degree in the University of London, England.

tions in 24-hour meteorological cycles. If light was a primary factor in the activation of natural populations in the 24-hour cycles, observed variations in correlations would suggest variable adaptation of mosquitoes to previous light conditions and to other physical and biological factors.

A quantitative investigation of the variable shift in periodicity of flight in mosquitoes would appear to depend, first, on the distribution of response among individuals in populations and, secondly, on its variation in time as a result of changes in physiological state. Therefore, laboratory experiments with an environmentally stabilized colony of *Aedes aegypti* (L.) were designed to elucidate the role of light in stimulating adult females to take off in various hygrothermally influenced physiological states. From the point of view of interpreting variations in populations, the effect of adaptation on response was determined in relation to 'time-intensity' measurements of the light stimulus.

General Methods

Colonization and stabilization of mosquitoes

The adult stock was maintained in standard mosquito cages at approximately 25°C and 72 per cent relative humidity. Eggs were hatched at 22-24°C. Larvae were reared at the same temperature on a slight excess of a standard food mixture of two parts (one light and one dark) of Entwistles[2] dog food and one part of Bemax[2] vitamin supplement. The food was ground to a fine powder and added daily in small amounts to the rearing dishes. Larvae were kept in small groups in eight or ten-inch glass dishes to avoid physiological variations resulting from overcrowding. Pupae were removed each morning either to be used as experimental material or to be placed in the rearing cages in another constant-temperature room to emerge and replenish the stock population. The adult stock was fed on a 5 per cent sucrose solution that was constantly available in soaked pads of cotton wool. Females were permitted to take blood meals from a rabbit two or more times a week depending on their ability to feed. Moist cones of filter paper inverted in petri dishes were available as a substrate for egg laying. Surplus eggs were kept on dried filter papers in the adult environment for periods up to two weeks for emergency restocking of the colony; but usually the newly laid eggs were flooded regularly for hatching.

Experience showed that the earliest pupations resulted in adults with shorter life spans whereas those from the last pupations had considerably less physiological vigour. Therefore, experimental material was selected from pupae appearing within the three days centred at the mode of the frequency distribution for pupation in individual rearing dishes. Pupae emerging in this period but not used, and all of the pupae composing the ends of the distribution, were transferred to the stock-rearing cages to maintain a stable heterogeneity comparable to the original generations. Experimental pupae were placed singly in special rearing tubes constructed from two glass vials of different size, 3″ x 1″ and 1½″ x ½″, with a common connection. The cork stopper of the larger vial was bored and fitted to form a tight collar around the mouth of the smaller one. When connected, the two vials formed a rearing tube (Fig. 1a). Thin sheets of plywood perforated with holes to accommodate the small vials according to a coordinate numbering system served as rearing-tube trays for large amounts of experimental material (Fig. 1b). The small vial containing a single pupa was filled with tap water, the large vial tightly inverted over the cork collar, and the whole assembly placed in a tray for emergence and conditioning of the adult at a constant

[2]British trade marks registered.

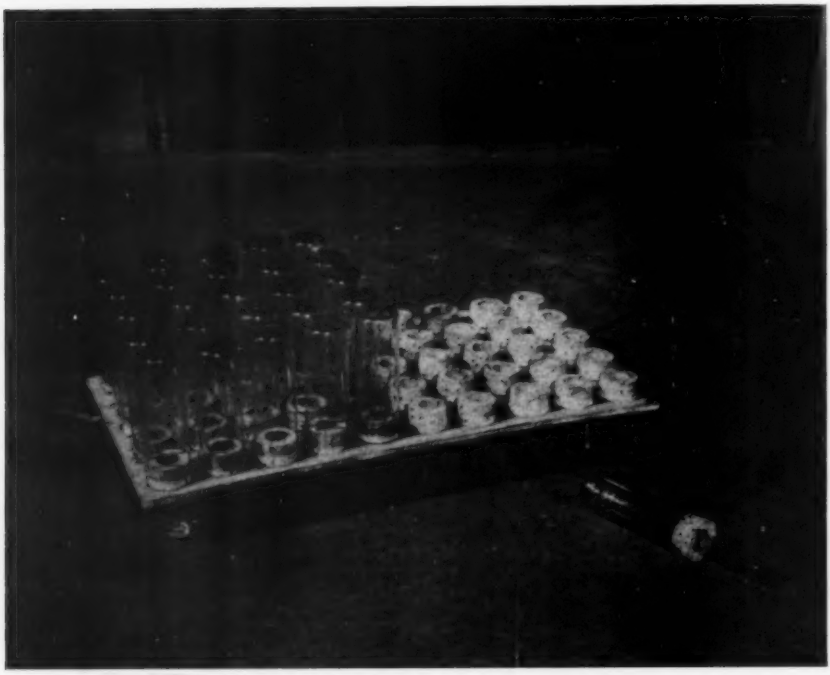

Fig. 1. (a) Rearing tube, (b) rearing tray.

temperature. Individual pupae were easily recorded in series against the coordinate system for consecutive daily experiments involving adult mosquitoes of known age groups. Trays were kept covered so that adult mosquitoes emerged in the dark and remained dark adapted until they were used in experiments. A saturated atmosphere was maintained in the rearing tubes by filling the smaller vials to overflowing and by soaking the cork collars previous to use. Condensation on the inside of the larger vial indicated that the air remained constantly saturated with moisture. Adult mosquitoes emerged and were maintained thereafter in 100 per cent humidity in a constant temperature room at 23 $\pm$ 1°C until they were used in experiments.

Experimental equipment

Working space was arranged in a dark cool basement room that fluctuated little in temperature and humidity except between the extreme seasons. The arrangement of essential equipment for the estimation of mosquito responses is shown in Fig. 2. A large constant-temperature water bath with glass sides (G) provided temperature control within $\pm$0.1°C during individual experiments. A copper chamber (C) with a clear space 4 x 10 x 16 inches and with a removable water-tight clear acrylic plastic[3] front panel (J) held the mosquitoes at known humidities. The chamber was supported rigidly below the water surface with minimum vibration by two tubular one-inch copper columns (S) clamped securely to a wooden frame (F) that rested on the top of the water bath. The tubular columns, in addition to their supporting function, served as ports to the

[3]Perspex, British registered trade mark.

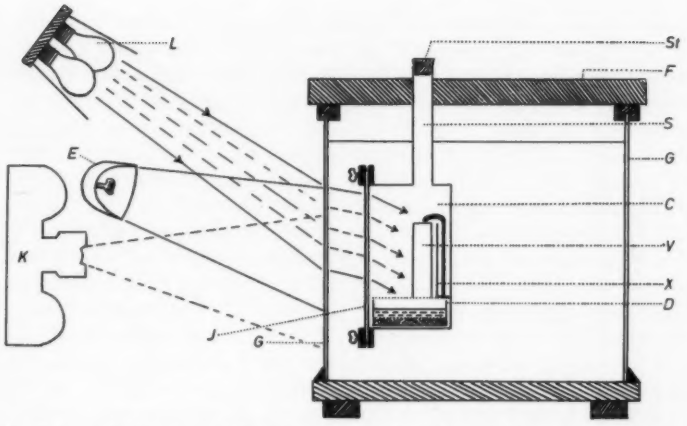

Fig. 2. Schematic diagram of the arrangement of equipment for measuring and recording displacement and activity of mosquitoes. L – light for stimulating flight, E – electronic flash unit, K – camera, G – glass side of water bath, J – transparent front of chamber, St – rubber stopper, F – wooden frame, S – tubular support, C – hygrothermally-controlled chamber, V – activity chamber, X – white back-drop with ruled grid, D – vessel with chemical solution.

inside of the chamber for the insertion of thermometers and humidity elements in the course of experiments. The orifice of the tubular frame was closed by a rubber stopper (S_t) after the chamber had been immersed and after the internal temperature had reached equilibrium with the bath. Otherwise positive or negative pressures built up inside the chamber. A shallow glass vessel (D) that fitted the floor dimensions of the chamber contained the chemical solutions for humidity control. A row of thirteen inverted 3 x 1 inch glass vials (V), each containing a single adult mosquito, was supported by a wire-net frame (W, Fig. 4) above the chemical solution. The bottom or open end of each vial rested on nylon gauze which prevented the escape of mosquitoes but allowed free molecular diffusion between the air inside the vials and that immediately above the chemical solution. The glass vials kept mosquitoes separate and also within a restricted depth of field for photographing.

A ruled grid (X) of black lines on a white background mounted permanently on the wire frame and immediately behind the row of vials served as a coordinate system for measuring mosquito displacement. A bank of seven 60-watt light bulbs (L) simulating bright sky light over an area approximately 4″ x 22″ was mounted in front and slightly above the bath to illuminate the inside of the experimental chamber. The incident brightness of light from this source could be controlled either manually in 27 non-rectilinear stages or mechanically at three reproducible rates, the median of which closely approximated the mean natural rate of increase or decrease of light at sunrise and sunset in summer at latitude 58° N. (Fig. 3). An automatic camera (K) recorded the displacement of mosquitoes at pre-arranged intervals with separate photographic illumination provided by an electronic flash unit (E).

Environmental conditioning

Experimental method was standardized in relation to time of exposure and sequence of treatments for three environmental factors – temperature, humidity and light. The optimum constant conditions promoting maximum longevity

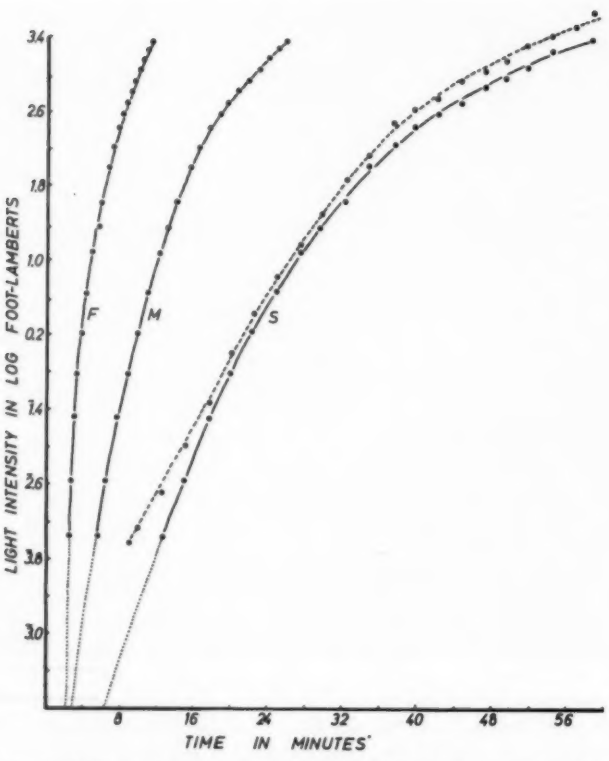

Fig. 3. Mechanically-operated reproducible rates of light stimulation used in experiments. Curves represent the rate of change in intensity of the stimulus with time corresponding approximately to daybreak (M), ½ the rate of daybreak (S), and twice the rate of daybreak (F). The broken line S shows the source intensity measured from the inside of the climate chamber immersed in the water bath as compared with that measured through air.

were determined and then used as the standard environment for preadaptation in experimental mosquitoes preceding all quantitative measurements of response. These conditions are given in the first section of the results. In the case of temperature and humidity, experimental material was theoretically adapted to a saturated environment at 22-24°C from the time the eggs were hatched until the adults entered any given experiment. Transfer of mosquitoes from rearing tubes to the climate chamber for experiment was usually done in less than 10 minutes in a very low intensity of indirect diffuse light. Adult females were in the prostrate state of immobilization during transfer with the exception of the older groups. During handling of middle and lower age groups there was no flight activity to influence adaptation and subsequent take-off. Six- and seven-day material was more difficult to handle. Prostrate immobility had usually been replaced by the tonic state and occasionally individuals flew as they were transferred between vials. A few old females that were prone to fly as a result of handling were excluded from experiments.

Unless stated otherwise, responses to light were measured in 80 per cent relative humidity at 28°C. The procedure in all experiments was to expose adult

females, emerged and conditioned in a saturated atmosphere, to an experimental combination of temperature and humidity. Response to a given light stimulus was measured following a one-hour period of adaptation to the hygrothermal change in complete darkness. The hygrothermal change was gradual since it depended on the time required for vapour pressure to reach equilibrium between the chemical solution and the air in the chamber. The time to achieve humidities within 3 per cent of the expected values varied from 38 to 59 minutes. For high humidities at the higher temperatures, preconditioning of the climate chamber was necessary to achieve less than the 3 per cent error in humidity within the alloted time. In this case the empty chamber containing only the chemical solution was sealed and immersed in the bath at the required temperature for two or three hours before the experiment. When the frame with the experimental mosquitoes was ready, the chamber was resealed. The copper chamber was an efficient heat conductor and, in cooling to room temperature, moisture condensed evenly on its inner walls. This film of moisture remained on the walls if the plastic panel of the chamber was removed in a cool humid room and replaced quickly as soon as the mosquitoes were introduced. When the chamber was returned to the same temperature in the water bath, the condensation evaporated immediately to provide the major portion of the water vapour in the required mixing ratio for the steady state. The function of the salt solution in this case was mainly to complete the latter stage of adjustment to the steady state and to maintain equilibrium at the required humidity. The course of the humidity change in the chamber was followed by lowering an electric hygrometer element through one of the ports and sealing the opening around the lead wire. The fluctuation in humidity due to thermostatic control of the bath was less than ± 1 per cent R.H.

Measurement of response

Posture changes manifesting certain physiological states (to be described in detail in another paper) and actual take-off were used as criteria in measuring response to stimuli. Physiological states related to the response observed in conditioned mosquitoes were interpreted according to biological definitions in Jones *et al.* (1949). The activity chambers were aligned in a horizontal row within the depth of field of the automatic recording camera. In practice the wire-net frame was tipped slightly to align the nylon gauze floor of the chambers with the line of sight of the camera lens (Fig. 4a). Schematic drawings (Fig. 4b) of a mosquito in coma or dead on its back (i), quiescent and at rest as in the prostrate completely dark adapted state (ii), and in the quiescent tonic state (iii) are shown in relation to the white background (x). The background (x) was raised slightly off the floor so that the body of a mosquito was plainly profiled in front only when it was elevated on its legs to the full extent characteristic of the active state. Dead mosquitoes that toppled over, those alive but in coma on their backs, and those that were completely dark-adapted and at rest in the prostrate position appeared below the white background close to the floor of the chamber. As long as mosquitoes remained on their feet in the tonic state, they were recorded in profile against the white background in consecutive film exposures. Periods of activity were defined by displacement recorded against the grid of black lines at predetermined intervals of time varying from a minimum of eight seconds to a maximum of twenty minutes depending on the level of activity measured. Individual exposures on film could be related to experimental time and to written observational logs through a chronological numbering system. An electrical counter with white figures on a black background was placed at the lower border within the camera field. It was operated

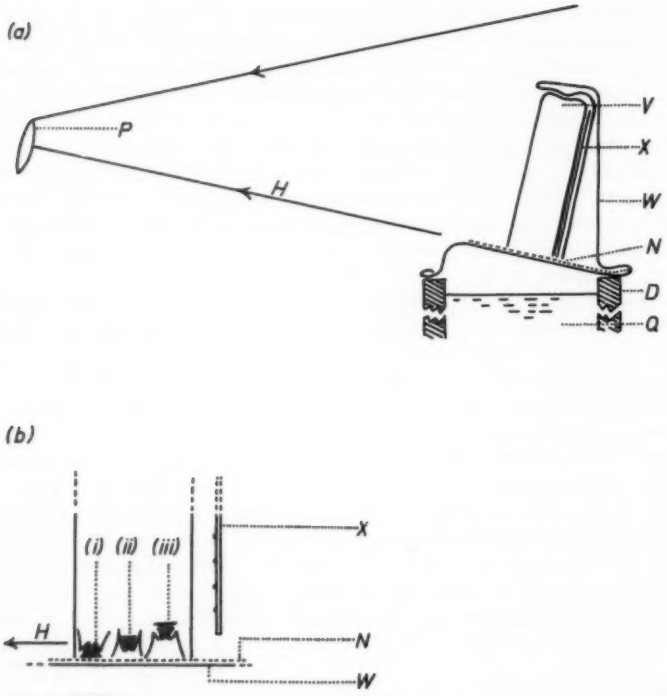

Fig. 4. Alignment of activity chambers with the camera. P – camera lens, H – line of sight of camera, X – white back-drop, V – activity chamber, W – wire frame, N – nylon gauze floor, D – glass vessel, Q – chemical solution, (i), (ii) and (iii) – postures of mosquitoes: in coma or dead, prostrate immobilization, and tonic immobilization respectively.

in electrical series with the film-transport circuit in the camera so that all exposures in film records were numbered consecutively against preset time intervals for each experiment. Luminous numbers on the electrical counter were also visible during the course of an experiment to facilitate identification of written observations of behaviour with the appropriate film records.

Results

Conditions for maximum longevity in 100 per cent R.H.

Environments saturated with moisture constitute an extreme to which adult mosquitoes are naturally exposed in any type of habitat. Normally the duration of these exposures is relatively short and the condition alternates with different degrees and rates of change toward the opposite extreme. A reasonable pre-experimental condition for uniformly adapted adults was considered to be a saturated environment at a temperature that supported maximum longevity combined with a healthy rate of emergence. This condition was determined with groups of forty pupae allowed to emerge in a saturated atmosphere at various temperatures in the dark. These results are summarized in Tables I and II. The most favourable temperature appeared to be between 20° and 24°C. Samples of mosquitoes conditioned for experiments were kept in the dark on the rearing trays at 23°C for three weeks to check survival in this temperature range. The

TABLE I
The relation between emergence and temperature for experimental mosquitoes

Temp., °C.	Total pupae	Total adults	No. failing to emerge	No. drowned	Healthy adults			
					Males		Females	
					No.	%	No.	%
16	40	14	26[1]	0	9	40[3]	5	29[3]
20	40	36	2	2(♀)	15	95[2]	21	87[3]
24	40	38	0	2(♀)	18	100	20	90.9
28	37	32	1[2]	4(3♀, 1♂)	14	100	18	94.7
32	40	34	3	3(2♂, 1♀)	15	81[3]	19	88[3]
36	40	28	2	10(6♂, 4♀)	15	68[3]	13	72[3]

[1] 2 female adults died partially emerged from pupal skin
[2] Partially emerged female
[3] General emergence of males precedes that of females. Assuming that the sex ratio in samples varies from approximately 1:1 depending on the time of selection from a brood, the theoretical estimate may be calculated to be

$$\frac{\text{No. of healthy survivors x } 100\%}{\text{Sex ratio of total No. emerging x No. of pupae in sample}}$$

longevity of 138 female and 136 male adults based on daily inspections is shown in Fig. 5. These numbers included only healthy individuals that emerged and successfully climbed to the cork surface in the rearing chambers (Fig. 1). Not included were five males and two females, representing less than four per cent of the total, that either chose or through lack of vigour remained on the water surface where they became hydrated and drowned within a few days. To maintain vigour, experimental groups of pupae for comparative measurements of adult response were selected within a three-day period of pupation spanning the mode of the distribution within each brood of larvae.

Adaptation time

Critical measurements of response in terms of 'time x intensity' of a stimulus depended on variations among individuals in their ability to adapt. Variation of

TABLE 2
The relation of temperature to longevity and emergence in a saturated atmosphere for starving mosquitoes in Table 1.

Temp., °C.	Mean longevity (days)		Longevity × % emergence	
	Males	Females	Males	Females
16	13.1 (10-18)	12.2 (9-16)	524.0	353.8
20	11.8 (9-17)	11.2 (9-14)	1121.0	974.4
24	11.4 (8-17)	9.1 (7-13)	1140.0	827.2
28	5.2 (3-11)	4.7 (3-9)	520.0	445.1
32	4.4 (3-8)	2.3 (1-5)	356.4	202.4
36	3.8 (1-5)	1.8 (1-3)	258.4	129.6

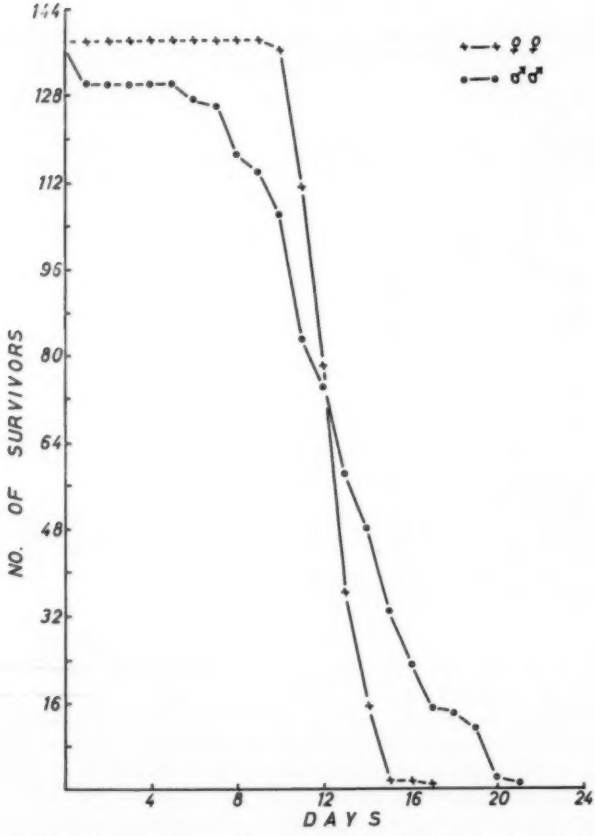

Fig. 5. Longevity of starving mosquitoes emerged and maintained in the dark at 23°C.

the empirical period for adaptation gave different results for mosquitoes exposed to a new environmental condition. The results of nine experiments with 12 mosquitoes each are shown in Fig. 6. The middle position in the series of thirteen chambers in these experiments contained the element of a Gregory electric hygrometer enclosed in a 3″ x 1″ glass tube as a check on the actual humidity influencing the mosquitoes *in situ*. A mechanically-operated reproducible increasing light stimulus (curve M, Fig. 3) was started at zero time in recording the accumulated frequency of take-off after various periods of adaptation in the dark. Mosquitoes were used 3½ days after emergence. The difference in the distribution of response between adaptation periods of 21-22 hours and 1-2 hours is shown at a relative humidity of 80 per cent and at temperatures of 24, 28 and 34°C. At 24°C only two out of twelve mosquitoes responded in two, and only three out of twelve in one of three experiments with a two-hour adaptation period. Even after 22 hours of dark adaptation, only ten out of twelve mosquitoes responded. The accumulated frequency among individuals varies with temperature as well as with adaptation time, i.e. some individuals adapt more quickly than others or some individuals have the ability to adapt more readily at different ranges of temperature.

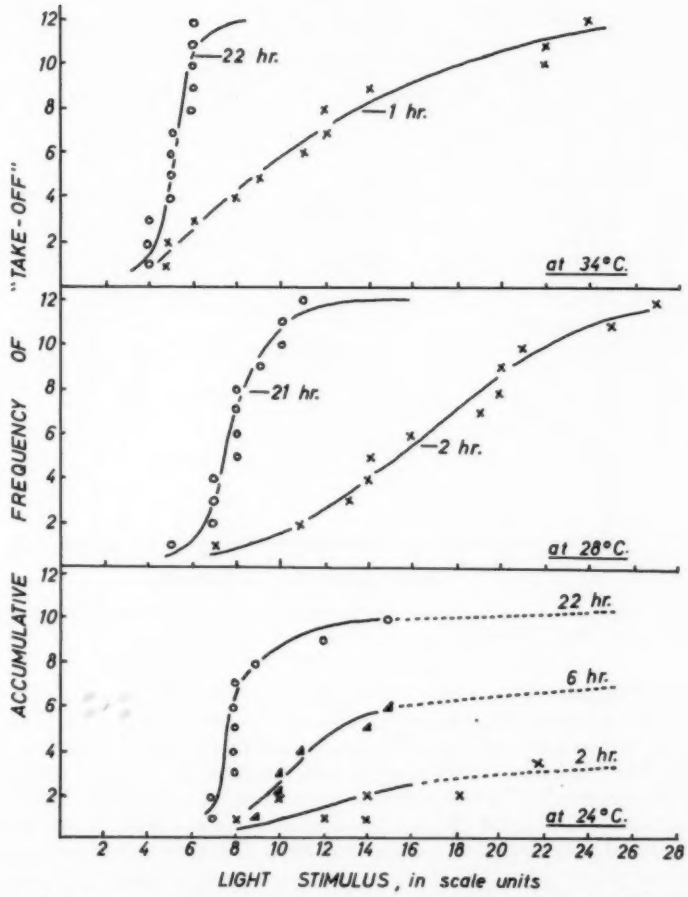

Fig. 6. Relation between cumulative take-off and adaptation time for different hygrothermal conditions.

Influence of previous activity

Experiments were run at 24.5°C and 80 per cent relative humidity to determine the effect of activity following previous light stimuli on the accumulated frequency of take-off. The lower temperature was chosen because it supports activity in the field and because the threshold for stimulatory excitation by light was higher. Mosquitoes were used at 5½ days instead of 3½ days so that a larger proportion of individuals in samples would be ready for activity, i.e. so that variation in time of stimulation as distinguished from intensity of stimulation could be reduced to a distribution within a thirty-minute period. A cumulative frequency of response of groups of thirteen mosquitoes was recorded within 30 min. following exposure at zero time to a constant light stimulus of 3.8 log foot-lamberts (Fig. 7). The middle curve (A) is the first response of a group to light after a two-hour dark-adaptation period. The light was switched off at the end of 30 min. and the same mosquitoes were dark-adapted again for two hours. At the end of this time the mosquitoes were exposed for the second time to the

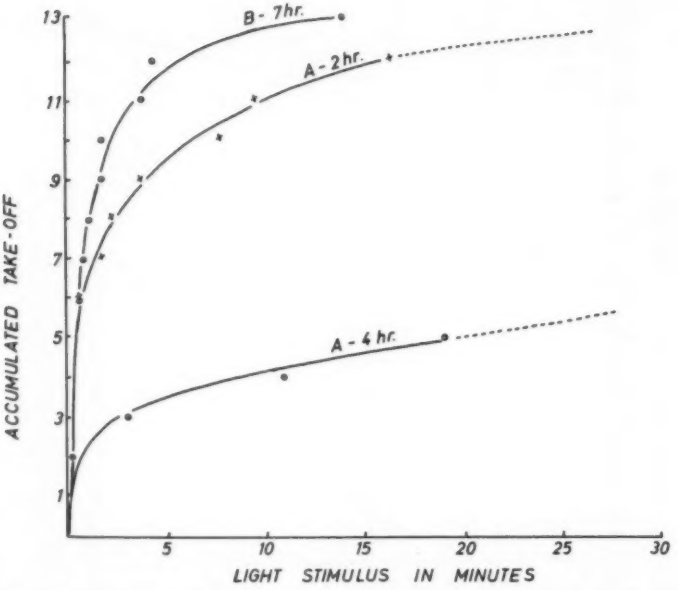

Fig. 7. Relation between cumulative take-off and previous activity at 24.5°C and 80 per cent relative humidity. (See text).

same light stimulus. The lowest curve (A) represents the accumulated take-off for the same group in response to the second stimulus. Only a fraction of the mosquitoes responded to the second as compared to the first stimulations in these experimental conditions. A third light period after a further two hours of dark adaptation produced a further reduced proportion of active individuals, usually as low as zero. Groups of thirteen mosquitoes from the same brood were dark-adapted to the same temperature and humidity for seven hours (approximately equal to the total adaptation of the first group to temperature and humidity at the beginning of the third stimulus). Group B (upper curve Fig. 7) represents take-off for these mosquitoes, all of which responded within the stimulus period. Previous activity diminished response to subsequent stimuli in a way similar to the reduced sensitivity that is observed at the neuro-physiological level in many reflex systems (Heilbrunn, 1952).

Influence of starvation

The effect of starvation on rate of adaptation was determined in a series of experiments with various age groups of starved mosquitoes at 24.5°C and 80 per cent relative humidity. The responses of these mosquitoes to constant light stimuli of 3.8 log foot-lamberts during 30 min. after various periods of dark adaptation in the experimental environment are shown in Fig. 8. With continuous starvation in the state of inactivity, response increased to the extent that 6½-day females took off at approximately the same rate after 2½ hours of adaptation as 3½-day females after 27 hours af adaptation. Female mosquitoes starved in a saturated atmosphere for periods up to 7½ days generally refused to take a blood meal or to feed on pads of cotton soaked with 5 per cent sucrose solution unless they were allowed time for activity including flight. For this

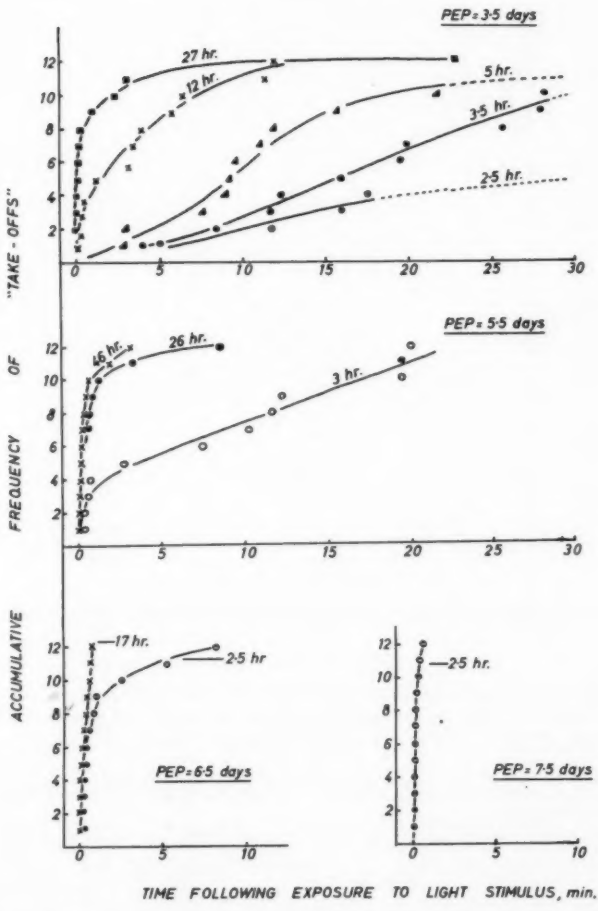

Fig. 8. Relation between cumulative take-off and starvation in mosquitoes at 24.5 degrees C. and 80 per cent relative humidity. PEP – post-emergence period.

reason attempts to measure the response of fed females following an inactive state were unsuccessful. Further experiments on the response of older blood-fed mosquitoes are described in a later paper.

Effect of adaptation time on distribution of response

Accumulated frequency curves (Fig. 6) indicated that the variation in response among individuals in experimental groups was related to both time of adaptation and temperature. Experience in using a probit transformation for cumulative response indicated that at temperatures above 34°C transformed data were not linear. Since, in experiments, some convenient transformations of responses depend on a normal distribution, it was necessary to examine the effect of high temperatures on the distribution of response for different periods of adaptation. This was especially important in devising experiments for the quantitative measurement of variations in response to hygrothermal changes in environ-

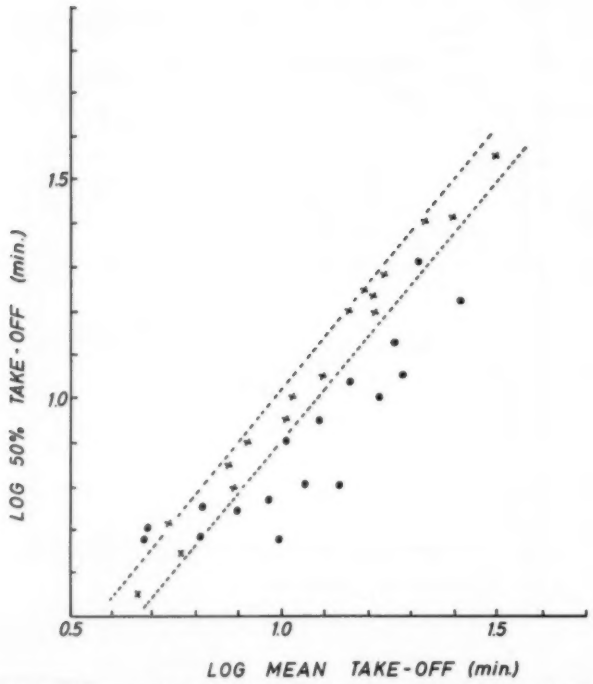

Fig. 9. Relation between the mean time of take-off and the time for 50 per cent take-off following standard light stimulus for groups of thirteen mosquitoes previously dark-adapted at 32°C (crosses) and 36°C (dots) for periods varying from one to 24 hours.

ment and also in selecting the length of adaptation periods preceding exposure to a standard stimulus.

Pairs of experiments were run at 32° and 36°C for different times of dark adaptation preceding exposure to a constant light stimulus of 3.8 log foot-lamberts. All experiments were done in an atmospheric water-vapour pressure of 38 millibars which is equivalent to 80 per cent relative humidity at 32°C and to 64 per cent at 36°C. Of seventeen pairs of experiments two accumulated frequencies followed each of one-, two-, three-, four- and six-hour periods; and one each followed eight-, 10-, 12-, 14-, 17-, 20- and 24-hour periods. If the distribution of response is uniform for the two temperatures, a plot of the 50 per cent accumulation of take-off in log time against the mean response in log time should form a rectilinear regression through the origin. The seventeen pairs of values were plotted for response at the two temperatures (Fig. 9). Each point is based on a group of 13 3½-day starved mosquitoes. The values for 32°C show reasonable rectilinearity and the regression passes close to the origin. A curvilinear regression for values at 36°C indicated a positively skewed distribution in relation to time for the majority of the experimental groups. Therefore, particular transformations such as the probit were limited in their application to responses within certain ranges of adaptation.

Adaptation in response to periodic stimuli

Variation in response of small populations to periodic stimuli was measured by keeping thirteen mosquitoes in the climate chamber under constant conditions

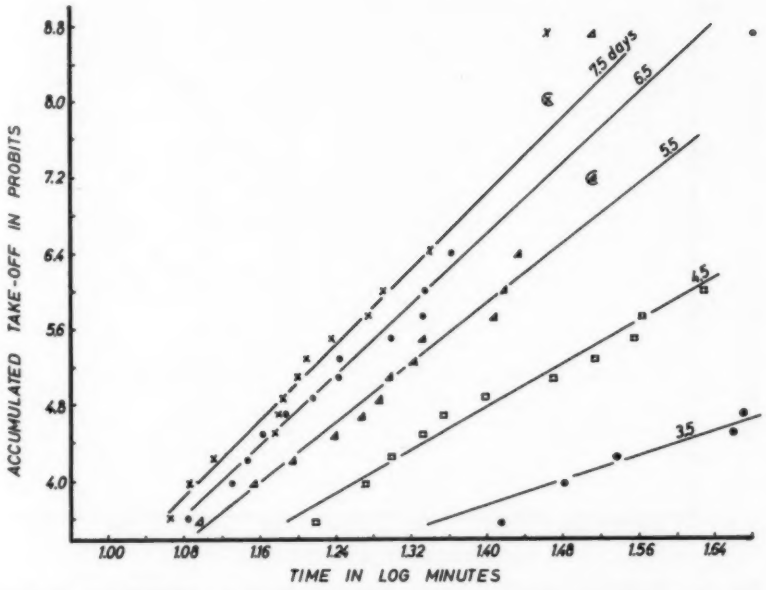

Fig. 10. Cumulative take-off of starving mosquitoes stimulated periodically at 24-hour intervals in 80 per cent relative humidity at 26°C.

of humidity and temperature for several days and subjecting them to a constant light stimulus at regular intervals of time spent in complete darkness. Temperature and relative humidity were 26°C and 80 per cent respectively. These conditions were selected as near average for a favourable environment supporting somewhat less than maximum activity. The periodic exposure to light stimuli was mechanically operated and reproducible over a 59-min. period (curve S, Fig. 3). The first group of 13 mosquitoes was confined to the experimental condition at 3½ days after emergence. They were allowed to adapt in the dark for four hours. At the end of this period they were exposed to the scheduled stimulus of increasing light intensity lasting 59 minutes. Accumulated take-off was recorded from zero time of stimulation until the light schedule reached its maximum at 3.4 log foot-lamberts. At the end of the light schedule the light was switched off and the mosquitoes remained in the dark for 24 hours. Then take-off was recorded again during exposure to the same scheduled light stimulus. This procedure was repeated after consecutive 23-hour dark periods until the final accumulated take-off was recorded at a post-emergence age of approximately 9½ days. The cumulative take-offs are plotted as probit transformations (Fig. 10). Only five individuals responded at 3½ days, 11 at 4½ days and 13 each day thereafter until 8½ days. The time for 50 per cent take-off decreased with consecutive 24-hour periods from the order of 60-70 minutes to approximately one minute. The slopes of the regressions increased with consecutive 24-hour periods up to 7½ days indicating that the variation in response between individuals was diminished with starvation or with a combination of starvation and age. There was no significant difference between the probit regressions at 7½ and 8½ days. One mosquito out of thirteen was dead at 8½ days and seven were dead at 9½ days. The regressions indicated that all individuals in the stabilized

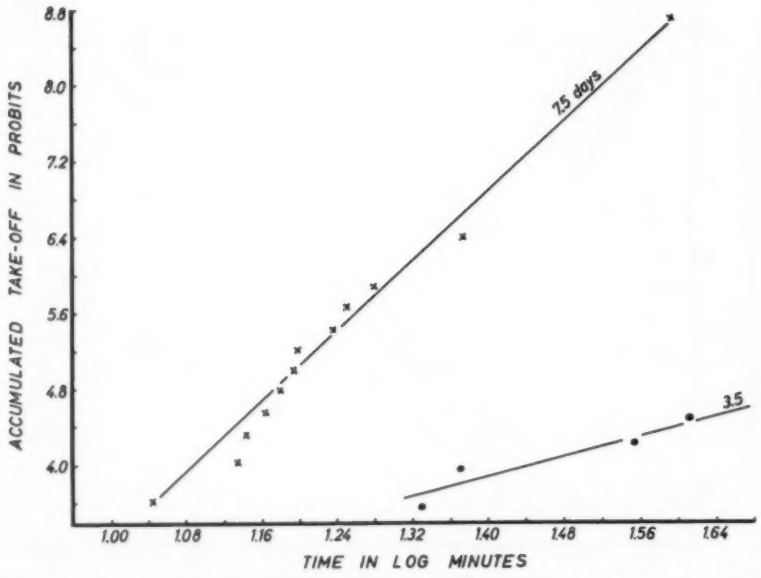

Fig. 11. Cumulative take-off of female mosquitoes stimulated after 3½ and 7½ days of starvation at 26°C and 80 per cent relative humidity.

colony responded to twenty-four hour light periodicity after starvation for 5½ days at 26°C and 80 per cent relative humidity. Skewing of the distribution of response among individuals became increasingly positive until a maximum was reached at 7½ days. The majority of individuals failed to become active before 3½ days except in response to long-term stimulation.

Maximum response at 7½ days was checked by repeating the experiment with a second group of thirteen 3½-day mosquitoes under the same hygrothermal conditions. The mosquitoes were initially exposed to the same light stimulus after 4 hours adaptation in the dark with a recording of cumulative take-off. They remained undisturbed in the dark for 4 days until the final exposure to the stimulus was made at a post-emergence age of 7½ days. Activity over the last 4-day period was monitored by electronic flash photography to which mosquitoes were insensitive in terms of activation. One mosquito was active in the dark by 6½ days and was dead at 7½ days. Therefore the transformation for cumulative take-off in this group (Fig. 11) is based on twelve instead of thirteen mosquitoes. It agrees closely with the 7½-day regression in Fig. 10, indicating that the cumulative take-off at 7½ days represented a maximum rate and minimum threshold for starving mosquitoes in the stabilized experimental colony.

A further experiment with a third group of 13 mosquitoes was designed to show the effect of a sustained stimulus in one of the 24-hour periods. The procedure of the first experiment was repeated at 4½ and 5½ days; but, following the recording of the accumulated take-off at 5½ days, the mosquitoes were continuously exposed to a constant light of 3.4 log foot-lamberts for a six-hour period. During this period the mosquitoes were allowed to remain active with consequent depletion of energy reserves. All showed tonic immobilization at the

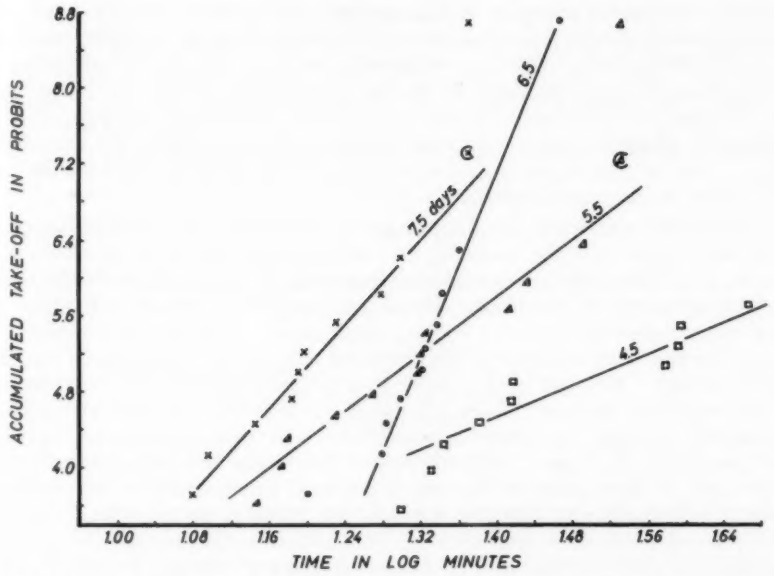

Fig. 12. Cumulative take-off of mosquitoes stimulated periodically at 24-hour intervals and allowed unlimited activity between 5½ and 6½ days of starvation.

end of the light period. This extended light period was followed by darkness for the remainder of the 24-hour period (18 hr.) at which time the regular procedure for light stimulation and dark adaptation was resumed. Fig. 12 shows the cumulative take-off for the successive 24-hour stimulations. The 4½-, 5½ and 7½-day regressions are comparable to those in the first experiment. The 6½-day regression has a significant increase in slope and the time for 50 per cent take-off is increased instead of decreased in relation to that at 5½ days. This effect appeared to be a result of the intense and prolonged activity on the previous day during the six-hour light period.

Mosquitoes simultaneously stimulated for short regular periods at 24-hour intervals showed a high correlation of rank order within uniformly selected groups from 4½ to 6½ days after emergence. In the third experiment (Fig. 12) there was a rank correlation ($T = 0.51$) significant at the one per cent level between orders of take-off at 4½ and 5½ days but no rank correlation ($T = .02$) at 5½ and 6½ days. Readiness to take off appeared to become random in succeeding periods of activity when mosquitoes were fatigued over long periods of stimulation in a favourable hygrothermal environment as in the 6-hour period at 5½ days.

Discussion

Flight in the post-teneral female adult of *A. aegypti* apparently depends on temperature and humidity, and light operates interdependently with the hygrothermal environment as a stimulus that reinforces excitation. These relations were observed and measured in individuals that were preconditioned to a saturated atmosphere at a steady temperature of approximately 23°C. The preconditioning environment represents an extreme in natural conditions encountered in the

field; but mosquitoes emerging in this condition are evidently adapted since they survive starvation for a mean period of 11-12 days if kept in complete darkness. One may interpret the adult preconditioning as a continuation of adaptation to the hygrothermal environment of the larval and pupal stages of development. The longevity at 23°C and 100 per cent relative humidity is not restrictive on theoretical grounds since the rearing procedure merely eliminated the normal need to adapt to new hygrothermal environments that abruptly influence the mosquito after its last metamorphosis.

Take-off in uniformly conditioned groups followed a normal distribution for favourable ranges of light, humidity, and temperature; but wide variations were observed for extremely unfavourable combinations of temperature and humidity. At high temperatures, especially above 34°C, responses among individuals approached the general form of a Poisson distribution. This variation appeared to depend on the 'time x intensity' parameter of adaptation to changes in environmental factors. It would appear to be an important factor in the interpretation of the imperfect 24-hour cycling of activity in the field. It may also account for the shift in periodicities that has been observed for individual species, especially since starvation with ageing altered rates of adaptation and subsequent response to changes in environmental factors. Results of experiments on adaptation to periodic stimuli showed that the length of the stimulus period would influence the form of population responses in consecutive cycles of 24-hour activity. Short-period stimuli produced a rank-order response in groups of uniform age so that the form of the distribution of responses among individuals was comparable for consecutive periods of activity although the mean threshold shifted with age. When mosquitoes of uniform age were fatigued during long-period stimuli, order of take-off was random between consecutive periods of activity at 24-hour intervals and the form of the distribution of response varied among individuals. This behaviour is an important aspect in the interpretation of 24-hour cycles of activity in the field. It suggests that wide variations in response to a given temperature, for example, probably depends on (1) the length of previous stimulus periods and (2) the variation in the age of populations contributing to the cycle of activity.

Summary

Rate of adaptation to light stimuli was measured in preconditioned *Aedes aegypti* female adults following changes in the hygrothermal environment. Rate of response to a standard stimulus among uniformly selected unfed mosquitoes increased with time between the experimental hygrothermal change and exposure to the light stimulus, decreased with activity preceding the stimulus, and increased with starvation and/or age. A normal distribution of response in time among uniformly selected individuals was observed for conservative changes of environment. Positively skewed distributions characterized responses to extreme changes, especially high temperatures. The variations in response due to adaptation were sufficient to account for the seasonal shifts in periodicity of 24-hour activity that occur in populations in the field.

Acknowledgements

Thanks are due to members of the staff at the Imperial College Field Station for interest and encouragement in the work, especially to Prof. O. W. Richards, for accommodating and directing the work in his department, Dr. R. E. Blackith, for valuable discussion of analytical problems and statistical designs, and Mr. J. W. Siddorn for helpful suggestions in photographic technique.

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A New Species of *Dasiops* (Diptera : Lonchaeidae) Injurious to Apricots

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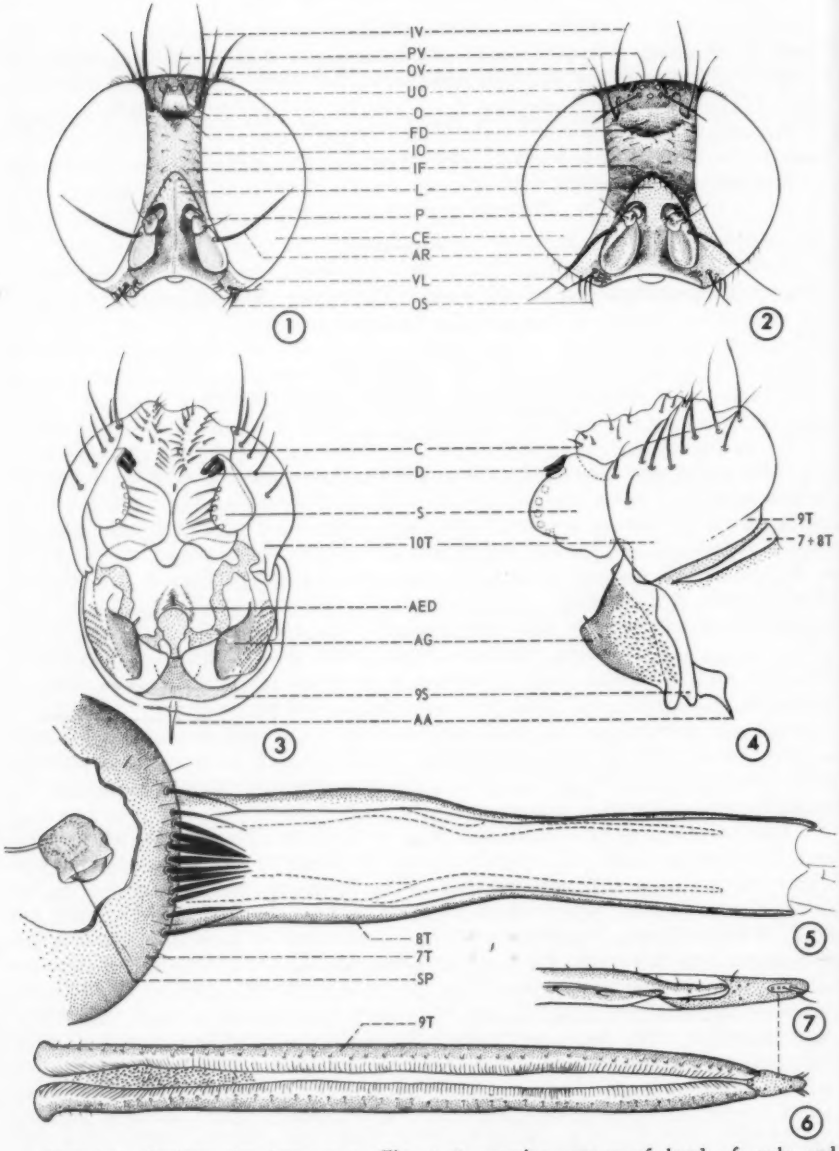
This paper describes a new species of the genus *Dasiops* Rondani, which is known to be a primary pest of apricot fruits in California (Moffitt and Yaruss, 1961). In common with other Lonchaeidae, the adult of this species is small (about three mm. long) and rather stout; with a shining, metallic blue-black body; the female possesses a long, piercer-type ovipositor (Figs. 5-7) similar to that of otitids and trypetids. Other characters that serve to distinguish the family include: black halteres, hairy frons which is narrower in the male than in the female (Figs. 1, 2), a single, reclinate upper frontal bristle, diverging postvertical bristles, a row of bristles near posterior margin of the mesopleuron, one or more sternopleural bristles and (usually) bare ptero- and hypopleuron. The genus *Dasiops* can be distinguished from other genera of Lonchaeidae by the presence of tiny, forwardly directed poststigmatal bristles which arise in the depression above the mesothoracic spiracle just cephalad of the anterodorsal corner of the mesopleuron.

I am indebted to G. M. Buxton, State of California Department of Agriculture, Sacramento, Calif., for the fine series of immature and reared adults from which the holotype was selected, and to the following persons for sending, or arranging the loan of, other valuable material: M. M. Barnes, H. R. Moffitt and F. T. Thorne, Citrus Experiment Station, University of California Department of Entomology, Riverside, Calif.; P. D. Hurd, University of California, Division of Entomology and Parasitology, Berkeley, Calif.; A. T. McClay, of the same Division, Davis, Calif.; E. L. Kessel, California Academy of Science, San Francisco, Calif.; C. W. Sabrosky, United States National Museum, Washington, D.C.; and M. R. Wheeler, University of Texas, Austin.

Dasiops alveofrons, new species

Length 2.0–2.75 mm. Shining bluish-black with strong metallic blue and blue-green reflections. Wings hyaline with a whitish cast. Calyptrae entirely white. Tarsi yellowish at bases. Frons shining metallic, bluish- or greenish-black with a deep, smooth, concavity in front of the ocellar plate.

Male.–Head (Fig. 1) oval in frontal view. Compound eye bare. Sides of frons almost parallel. Frons shining, bluish or greenish-black, usually with strong metallic lustre; lightly whitish-grey pollinose anteriorly; with a deep, smooth, more or less transverse, depression immediately in front of anterior ocellus, and between and slightly below the orbital bristles with eight or nine inferior orbital setulae, none arising dorsad of the orbital bristle; frontal vitta



Figs. 1-6. *Dasiops alveofrons* n.sp. Figs. 1, 2, anterior aspects of head of male and female, respectively. Figs. 3, 4, male genitalia, ventral and right lateral aspects respectively. Figs. 5-7. Female terminalia. Fig. 5, apex of sixth tergum and basal segment of ovipositor (with spermatheca inset) dorsal aspect. Fig. 6, penultimate and apical segments of ovipositor, dorsal aspect. Fig. 7, apical portion of ovipositor, left lateral aspect.

(AA, aedeagal apodeme; AED, aedeagus; AG, anterior gonopophysis; AR, arista; C, cercus; CE, compound eye; D, tooth of surstylus; FD, frontal depression; IF, interfrontal setula; IO, inferior orbital setula; IV, inner vertical bristle; L, lunule; O, ocellar bristle; OS, oral setula; OV, outer vertical bristle; P, parafacial; PV, postvertical bristle; S. surstylus; SP, spermatheca; 9S, ninth sternum; 6-9T, sixth-ninth terga; UO, (upper) orbital bristle; VL, vibrissa-like bristle).

with four or five mesally curved interfrontal hairs arranged in an irregular row on each side of the midline. Postvertical bristles parallel to slightly divergent. Lunule acutely arcuate above; densely silvery pollinose except on narrow margins which bear eight setulae; with a weak median groove anteriorly. Face and parafacials intensely (though less so than lunule) silvery pollinose, especially in anterodorsal views. Parafacials narrow. Shortest distance between oral margin and compound eye subequal to greatest width of third antennal segment. Cheek with four relatively strong vibrissa-like bristles; above these with one to three smaller mesally curved bristles. Antennae entirely brownish-black; third segment almost one and one-half times as long as wide (3.6 : 2.5). Arista dark brown, micropubescent; thickened on basal one-sixth; penultimate segment about twice as long as wide.

Thorax strongly shining blue-black; pollen scarcely evident except in oblique anterior views. Bristles of mesonotum strongly differentiated from hairs; with one pair of prescutellar acrosticals and, on each side, with two postsutural dorsocentrals, the anterior one weaker, two postalars, one postsupraalar, one humeral and one posthumeral (=presupraalar). Scutellum with four bristles, without additional hairs. Pleuron with the following bristles: one propleural, one stigmatal (=epimeral), two poststigmatals, several weak anterodorsal mesopleurals, five posterior mesopleurals, two notopleurals, and one sternopleural. Prosternum and pteropleuron bare.

Femora and tibiae black. Front metatarsus, and two basal segments of mid and hind tarsi yellow; tarsi otherwise brownish-black.

Wings hyaline to naked eye but pale milky-white under low magnification; veins yellow.

Abdomen shining bluish-black, usually with a faint silvery-greenish lustre; slightly longer than broad; last apparent segment about one-third longer than either of the two preceding segments.

Genitalia (Figs. 3, 4): In side view epandrium rather rectangular; surstylus somewhat fist-shaped. The latter with two stout, blunt, rather sinuate teeth on posterior lobe. Hypandrium with a low, blade-like lobe on each side of phallus, each of these lobes spiculate laterally and each bearing a small setula near the apex on the mesal surface. Phallus little more than a spout-like opening. Aedeagal apodeme relatively small.

Female.—Differing from the male as follows. Head (Fig. 2) broader in proportion to its height. Frons much broader and less narrowed anteriorly; frontal depression larger and distinctly transverse. Postvertical bristles more strongly divergent. Front tarsus often with two basal segments yellow.

Ovipositor (Figs. 5-7) with sides of penultimate segment (Fig. 6) almost parallel on basal three-fourths, gently narrowed on apical fourth; apical segment not very sharply pointed (Fig. 6), with a pair of very fine dorsal setulae near base, a similar pair of ventral setulae near apex, and two larger setulae on each side near apex (Fig. 7). Seventh tergum with a fascicle of 12 stout bristles at the middle of the hind margin (Fig. 5). Fifth and sixth sterna with long, median, anteriorly directed apodemes, the one on the latter larger. Spermathecae (Fig. 5) three; somewhat cup-shaped.

Mature larva.—(Figs. 8-13). Length 7.0—7.75 mm., white, consisting of 12 segments. Slightly broader than deep in cross section; broadest at fourth and fifth abdominal segments; last segment rather truncate. Pseudocephalon with two pairs of sensory papillae, anterior pair about one-half size of posterior pair.

Mouth hooks (Fig. 13) stout; apical portion fairly strongly curved; labial and subhypostomal sclerites strongly developed; hypostomal sclerite wedge-shaped, heavily sclerotized; ventral cornua of pharyngeal sclerite broad, with two small pigmented areas at apex; dorsal cornua much smaller, dorsal margin evenly convex except near apex, almost parallel to ventral margin of ventral cornua.

Anterior spiracle (Fig. 9) with six (sometimes five) branches arranged fanwise.

All abdominal segments with ventral, spinous, locomotory pads (Fig. 10); spinules of each pad reclinate, arranged in from two to five rows as follows: segment one, one anterior and one posterior row; segment two, two anterior and one posterior row; segment three, two anterior and two posterior rows; segments four to eight, each with three anterior and two posterior rows.

Posterior spiracular plate (Figs. 11, 12) on a heavily sclerotized, stump-like projection bearing three dorsally directed teeth, the middle one largest and most conspicuous in side view; slits oval, radially arranged.

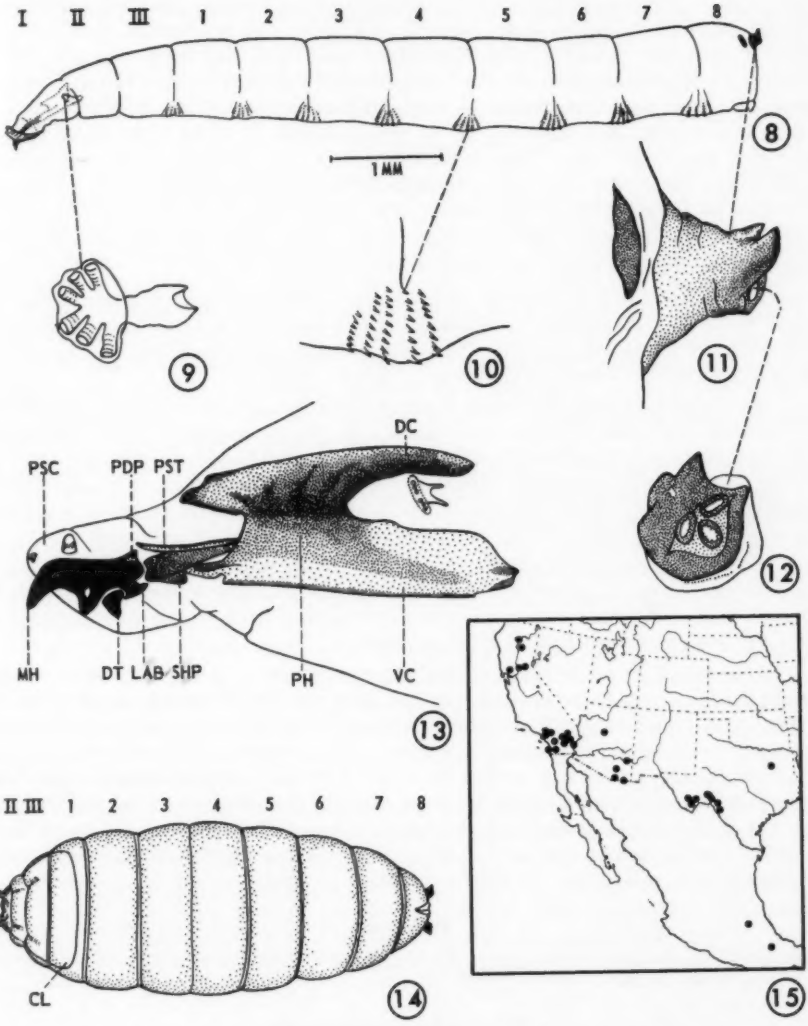
Last abdominal segment, laterad of each spiracular tubercle, with a lens-shaped, pigmented spot (Fig. 11).

Puparium.—(Fig. 14). Length 4.0 mm.; width almost 1.5 mm. Reddish-brown; smooth and shiny. Vertical diameter slightly less than horizontal diameter. Intersegmental articulations distinctly, but not very deeply constricted. Anterior spiracles smaller and a little more widely separated than posterior ones. Transverse cleavage line at about posterior third of first abdominal segment. Eighth abdominal segment dorsally with a crater-like median furrow and ventrally with a transverse, mouth-like groove about midway between anterior and posterior margin. Posterior spiracles prominent; with a heavily pigmented, depressed spot dorsolaterad of base of each.

Holotype, ♂, *and allotype*, ♀, Redding, Shasta Co., Calif., July 1, 1959, emerged July 22, 1959, reared from apricots, B. Wade collector.

Paratypes (all from CALIF.), 32 ♂♂, 28 ♀♀, same data as holotype, emerged July 22, Aug. 1, 1959; 1 ♀, Alpine, San Diego Co., July 25, 1956, primary pest of apricot fruit; 12 ♂♂, 7 ♀♀, Alpine, San Diego Co., July 21, 1959, reared from apricot, H. R. Moffitt; 1 ♂, Andreas Canyon, Palm Springs, Mar. 11, 1955, W. R. M. Mason; 1 ♂, Auburn, Placer Co., July 19, 1950, reared from currants, E. Gammon; 1 ♂, Blythe, Apr. 24, 1955, W. R. M. Mason; 1 ♀, 10 mi. n. w. La Paz, Oct. 6, 1941, Ross and Bohart; 1 ♀, Millard Canyon, July 22, 1949, M. Wheeler; 1 ♀, Pacific Palace, L. A. Co., Oct. 7, 1951; 1 ♂, 1 ♀, Pasadena, July 4, 1949, M. Wheeler; 3 ♂♂, 2 ♀♀, Placerville, Oct. 7, 1953, reared from codling moth?, E. I. Schlinger; 1 ♀, 29 Palms, S. Bernardino Co., Mar. 29, 1952, E. I. Schlinger; 1 ♂, San Diego Co., Jan. 18, 1919, E. P. Van Duzee; 1 ♀, San Gabriel Rio, Oct. 1, 1949, M. Wheeler; 3 ♂♂, 3 ♀♀, Riv. Co., fall, 1958, walnut husk, H. R. Moffitt; 3 ♂♂, 2 ♀♀, Red Bluff, Tahama Co., Oct. 9, 1957, reared from walnut husk, E. L. Dietz; 3 ♂♂, 2 ♀♀, Hemet, Rivers Co., Sept. 29, 1959, ex walnut husk, H. R. Moffitt; 1 ♂, 1 ♀, Rivers Co., fall, 1959, ex walnut husk, H. R. Moffitt; 1 ♂, San Jacinto Mts., July 21, 1929, R. H. Beamer; 1 ♂, Snow Creek, White Water, 1500 ft., Mar. 22, 1953, W. R. M. Mason; 2 ♂♂, Sonoma, Sonoma Co., Sept. 12, 1954, reared from Persian walnut, B. Beardon; 1 ♂, 2 ♀♀, Sonoma, Oct. 12, 1954, reared from *Juglans regia*, E. Swift.

Other material of this species from the following localities: ARIZ.: 1 ♀, Flagstaff, 7.9.1948, N. S. Baily; 2 ♂♂, 2 ♀♀, Graham Co., Aug. 25, 1930, reared ex walnut husk, J. H. O'Dell; 1 ♂, Naco, Oct. 1942, 13048; 15 ♂♂, 15 ♀♀,



Figs. 8-13. Larva of *Dasiops alveofrons* n.sp. Fig. 8, left lateral aspect of mature larva. Fig. 9, anterior spiracle. Fig. 10, arrangement of spines on fifth locomotory pad. Fig. 11, lateral aspect of left posterior spiracle. Fig. 12, caudal aspect of left posterior spiracle. Fig. 13, buccopharyngeal skeleton of mature larva, left lateral aspect. Fig. 14, puparium, dorsal aspect (same scale as larva). Fig. 15, known geographic distribution.

(CL, cleavage line of operculum; DC, dorsal cornu; DT, dentate sclerite; LAB, labial sclerite; MH, mouth hook; PDP, posterodorsal process of mouth hook; PH, pharyngeal sclerite; PSC, pseudocephalon; PST, parastomal sclerite; SHP, subhypostomal sclerite; VC, ventral cornu; I-III, first to third thoracic segments; 1-8, first to eighth abdominal segments).

Nogales, Jan. 8, 1951, reared from dead sunflower stems, Nogales 55671; 1 ♀, Oak Creek, July 14, 1937, L. D. Christenson; 1 ♂, Tucson, July 1925, 2400 ft., reared ex *Juglans major*, R. B. Streets. TEXAS: 2 ♀♀, Austin, Apr. 27 and May 4, 1951, M. Wheeler; several hundred specimens, Big Bend Nat. Pk., May 1959, J. F. McAlpine; 20 ♂♂, 2 ♀♀, Comstock, Apr. 28, 1959, "Dancing" under mesquite tree, J. F. McAlpine; 2 ♀♀, Dallas, Mar. 19, 1908, F. C. Bishop; 3 ♂♂, 3 ♀♀, Del Rio, Oct. 13, H. M. Brundett; 50 ♂♂, 10 ♀♀, Devil River, nr. Del Rio, Apr. 26, 1959, swarming under tall shrubs, J. F. McAlpine. MEXICO: 9 ♂♂, 1 ♀, Pachuca, Hildago, July 29, 1954, 1700 ft., J. G. Chillcott; 2 ♀♀, Teotihuacan, Pyr. Mex., July 7, 1951, P. D. Hurd.

Holotype, allotype and paratypes deposited in State of California Department of Agriculture Collection, Sacramento.

Paratypes also in University of California Citrus Experiment Station, Riverside, California Academy of Sciences, San Francisco, United States National Museum, Washington, Canadian National Collection, Ottawa, and in the collection of Dr. M. R. Wheeler, University of Texas, Austin.

Remarks:—*Dasiops alveofrons* is about the same size and shape as *D. albiceps* (Malloch) but differs from that species in having entirely white calyptrae (fringes brownish in *albiceps*) and bare prosternum (haired in *albiceps*), and in being more highly polished. *Dasiops bourquini* (Blanchard), and *D. chiesae* (Blanchard) reared from *Opuntia* sp. in Argentina apparently are closely related to *alveofrons*, but they are both described as being black with yellowish calyptrae.

Dasiops alveofrons is widely distributed in the south-western United States and Mexico (Fig. 15) where it seems to be confined mostly to the Lower Sonoran Faunal Zone. As indicated above, it has been reared from walnut husks, currants, and sunflower stems as well as from apricots.

I observed the adults many times dancing and hovering in loose swarms under mesquite trees and high shrubs in the Del Rio and Big Bend regions of Texas in May 1959. Each "swarm" contained from a few to up to a hundred individuals and was made up almost entirely of males. The swarms were usually two to five feet above the ground and, within them, the individuals moved silently back and forth and up and down through shafts of sunlight that penetrated the leaf canopy. In this way their glistening bodies easily caught one's attention. At night large numbers could be obtained on a beating sheet by beating shrubs and small trees, especially mesquite trees. A few males came to light.

Reference

Moffitt, H. R. and F. L. Yaruss. 1961. *Dasiops alveofrons* McAlpine (Diptera: Lonchaeidae), a new pest of apricots in California. In press, for publication in Jour. Econ. Ent.

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Observations on Males and Females of *Sitophilus granarius* (L.), the Granary Weevil, GG Strain, Exposed for Six Generations to Allethrin and Piperonyl Butoxide

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Introduction

In a recent discussion of the subject of insect resistance to insecticides, Brown (1958) has claimed that true resistance is characterized by a five-fold to ten-fold decrease in susceptibility. It is a genetic phenomenon arising as a result of selection. There is no evidence that insecticides are mutagenic, nor can resistance be induced by exposing insects to sublethal doses. A decrease in susceptibility that cannot be regarded as resistance is regarded as a condition of tolerance. In addition, the term "vigour tolerance", introduced by Hoskins and Gordon (see Brown, 1958) defines instances of enhanced tolerance due to extra vigour: true specific resistance is marked by a change of slope in the dosage-mortality regression line, while "vigour tolerance" is suggested if the regression line shifts but does not change in slope.

Recently Orr (1958) has investigated the effects of lindane on *Sitophilus granarius* (L.), the MW strain (Musgrave and Miller, 1958), for a series of generations. He reared the weevils on lindane-treated wheat and also exposed them to direct spray. Those reared on the treated wheat were undoubtedly handicapped in their development, while the sprayed weevils eventually exhibited a significant tolerance. It seemed too that exposure to lindane selected the heavier weevils.

Little work has been done with *Sitophilus granarius* and allethrin, which is usually regarded as one of the least hazardous insecticides – an important point in the control of stored products pests. The present paper describes experiments in which the granary weevil, *S. granarius*, GG strain (Musgrave and Miller, 1958), was exposed for several successive generations to deposits of a mixture of allethrin and piperonyl butoxide.

Early in the present work a new, simple method of determining accurately the sex of *S. granarius*, GG strain, by external characters was developed. It has been described elsewhere (Sevintuna and Musgrave, 1960). This finding permitted studies of differential susceptibility of the sexes to the insecticide, as has been possible in other species of insects (Bruce, 1950; Harrison, 1952, 1954; Pimentel, Schwardt and Dewey, 1953, 1954; Busvine and Khan, 1955). The investigation received valuable help from the results of ground work done by Orr (1958) on the MW strain.

Material and Methods

General Approach

After reviewing a great number of possible techniques of exposing insects to insecticides (Busvine, 1957), a simple method of residual deposits on filter papers was decided upon. Several other techniques were tried.

Two control populations of weevils were employed: one for determining the natural mortality rate under the conditions of rearing; the other for determining if factors other than the insecticide, and attributable to the testing technique employed, were contributing to mortality.

As described later, steps were taken to prevent the weevils from mating before they were exposed to the insecticide, so that males destined to be killed

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by the insecticide would be unable to donate sperm to females destined to survive. In this way it was hoped to prevent dilution of such factors for resistance as the females might be carrying.

Chemical Materials

Allethrin used throughout the investigation was 90% allethrin (Tech.) sold by Nutritional Biochemicals Corporation, Cleveland, Ohio. The piperonyl butoxide was a technical grade: butyl carbitol 6 propyl piperonyl ether 80%, related compounds 20%, U.S. Patent No. 2,485,681, sold by the Fairfield Chemical Division, Food Machinery and Chemical Corporation, Baltimore, Md. The acetone used as solvent had B.P. 55.5-55.8°C. and was sold by Canadian Laboratory Supplies Limited, Toronto, Ont. Piperonyl butoxide and allethrin were used in a 10:1 ratio: for example, an 11% solution was prepared by adding 10 ml. of piperonyl butoxide to 1 ml. of allethrin and dissolving the 11 ml. in 89 ml. of acetone.

Application Procedure

Whatman No. 3 filter papers (11 cm. diameter) were temporarily supported on glass rings 2 cm. high and 7.63 cm. in diameter. Two ml. of insecticide material of appropriate concentration were applied to the centre of each filter paper by means of a syringe or burette. Conditions were standardized as much as possible by maintaining the applicator 5 cm. distant from the paper and allowing evaporation of the acetone at 24° ± 1°C. and 60-65% R.H. Papers on which the insecticide spread out by more or less than an accepted arbitrary standard were discarded.

Biological Materials

a) *Rearing*

The weevils, *Sitophilus granarius*, were reared on Canadian grown wheat (var. Genesee), in large jars of 500 ml. capacity. Before use the wheat was autoclaved at 15 lbs./sq. in. for 15 minutes at 121°C. to rid it of any existing insect infestation. It was then conditioned for three weeks in jars in a humidor with an atmosphere of 75% R.H. and 27° ± 1°C., to bring it to a water content acceptable to the weevils. Openings of jars were covered by brass riddle cloth or (in all the later work) with plastic screening. Weevils were reared and kept after treatment at 27 ± 1°C. and 75% R.H.

b) *Collection of Weevils*

Weevils were collected from the grain by spreading it on stiff paper on the bench under a bench lamp. As the weevils left the grain they were sucked into a 250 ml. flask.

General Experimental Procedure

In most of the work weevils of known age were used. At time of test they were usually 7 ± 2 days old. Spermathecae of fifteen female weevils of up to two days old that had had opportunities for mating were found by dissection to contain no sperm. It was therefore assumed that copulation did not take place in the first two days of adult life. The sexes were therefore segregated when two days old and kept in small jars of 65 ml. capacity containing 30 gm. of grain. Using a small brush to overturn the weevils and taking 5 at a time, it was possible, in 45 minutes, to determine the sex of 100 weevils. In order to prevent overcrowding on the filter paper, no more than 24 weevils were exposed at a time on any one paper. Weevils were confined on the filter papers by glass

rings, 7.6 cm diameter, covered by petri dishes and were thus free to roam over the toxic substrate and the confining glass.

These experiments were done at 24° ± 1°C. and 60-65% R.H. After treatment, weevils were kept in small 65 ml. glass jars containing 30 gm. wheat, for 7 days; mortality was then assessed.

Dose-Response Relationships During Successive Generations of Exposure to Insecticide

A. *Code*

In order to simplify the reporting of the results, the following legend has been used.

S series: the weevils exposed for successive generations to the insecticide.

T series: the weevils from the same original stock culture as the S weevils handled in the same way as the S weevils but not exposed to insecticide – technique control.

N series: from the same stock as the S weevils but simply reared on wheat for successive generations – natural mortality control.

The first generation weevils are referred to as S_1, T_1, N_1, the second S_2, T_2, N_2 and so on.

Emergence Group: weevils that emerged from a culture during a given time interval, e.g. those that emerged in numbers within the first 48 hours were emergence group one, within the next 48 hours were emergence group two and so on.

B. *Preliminary Experiments to Assess Dose-Mortality Relationships of Weevils*

A series of tests was made with weevils (7 ± 2 days old) at different doses of insecticide and different periods of exposure. These tests were done before the method of determining the sex of the weevils had been devised. The tests indicated that a 50% mortality (LD_{50}) resulted from exposure for 1 hour and 75% (LD_{75}) mortality from exposure for 1½ hours, to a deposit of 2 ml. of 44% of the allethrin-piperonyl butoxide mixture. These results permitted a reasonably accurate prediction of the LD_{50} and LD_{75} to be made.

C. *Male and Female Weevils*

Tests with male and female weevils of different ages were made. The two sexes were exposed at the same time, for the same duration on any one filter paper. The mean mortalities of males and females were found to be significantly different by analysis of variance tests (Cochran and Cox, 1957). Females could tolerate higher doses than males.

D. *Level of Selection Pressure*

Two levels of selection pressure were tried – LD_{50} and LD_{75}. It was found that an insufficient number of weevils survived at the LD_{75}. The greater part of the work was therefore done by exposing weevils to a predicted LD_{50}.

E. *Exposure to Insecticide for Successive Generations*

i) *First generation* (S_1, T_1 and N_1)

From a laboratory stock culture of GG strain weevils the following were removed: a) 110 males and 110 females, which were segregated two days after emergence had begun and were exposed to the appropriate LD_{50} mixture (a deposit of 2 ml. of 44%: males exposed 1 hr., females 1¼ hrs.), when 7 ± 2 days old (S_1 weevils);

b) 30 males and 30 females, which were handled in a manner identical with the S_1 weevils and on the same day, except that they were not exposed to insecticide but placed on untreated filter papers (T_1 weevils);

c) 100 weevils of undetermined sex, which were simply set up to form a culture on 250 gm. of wheat in a large jar (the N_1 weevils).

The male and female S_1 weevils were exposed (the two sexes simultaneously) to the insecticide deposits in replicates of about 20 weevils each. Males were removed after 60 minutes, females after 75 minutes. The male and female weevils were kept segregated in small vials with wheat for 7 days. Mortality was then assessed and the dead weevils discarded. Results are given in Table I.

The 51 male and 50 female S_1 weevils that survived the treatment were placed together in a small jar, of 65 ml. capacity, containing 30 gm. of wheat. A small jar was used to increase the opportunities for the sexes to meet and mate. After two days they were placed in a large jar, capacity 500 ml., on 250 gm. of wheat. Thirty days from the day of the mortality counts, all adult weevils were removed from this jar but the wheat was kept. Seven days later, weevils began emerging from this wheat. They were the S_2 weevils – the progeny of the S_1 weevils.

The 30 male and 30 female T_1 series weevils were similarly treated and the T_2 series obtained.

The N_2 series weevils were obtained simply by sub-culturing the N_1 series.

ii) *Second Generation (S_2, T_2 and N_2)*

As emergence of the S_2 and T_2 series weevils proceeded, all weevils were cleared off the grain every two days. One of the emergence groups was used for exposure to selection pressure. The weevils of this group were segregated according to sex and held in separate jars with grain until they were 7 ± 2 days old, when they were exposed to filter papers just as the S_1 and T_1 weevils were. Results are given in Table I.

Weevils were held for 7 days before assessing mortality. Then the 32 male and 34 female surviving S_2 weevils and the 30 male and 30 female surviving T_2 weevils were processed in the same way respectively as the surviving S_1 and T_1 weevils; and the N_2 weevils were processed like the N_1 weevils. In this way S_3, T_3 and N_3 weevils were obtained.

iii) *Subsequent Generations*

As there was evidence that the weevils of different emergence groups might be different in weight (Richards, 1948) it seemed likely that prediction of the LD_{50} would be more accurate if, in each generation, weevils of the same emergence group were used, as body weight and susceptibility to toxic materials are usually directly related. This was simply a device to facilitate prediction of the LD_{50} and was used in the third, fourth, fifth and sixth generations. These were exposed to selection pressure, employing the same method as for the second generation, except that the second emergence group of weevils was always used. The results are given in Table I. It can be seen that the sixth generation weevils had a higher LD_{50}, as expressed by an increased period of exposure.

Experiments to Test for Decrease in Susceptibility

In order to see if exposure of weevils to the insecticide had selected less susceptible weevils, two tests were carried out in which the S series weevils were compared at graded doses with the T series weevils and the N series weevils.

TABLE I

Experimental data of successive generations of *Silophilus granarius* GG strain. S series, exposed to filter papers treated with allethrin and piperonyl butoxide (2 ml. of 44% of mixture). T series, technique control.

Generations	S_1		T_1		S_2		T_2		S_3		T_3		S_4		T_4		S_5		T_5		S_6		T_6	
Sex	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Number of replicates	5	5	2	2	4	4	2	2	2	2	2	2	3	3	3	3	3	3	3	3	2	2	2	2
Total number tested	110	110	30	30	60	60	30	30	28	32	20	20	40	60	40	40	45	50	40	40	27	26	15	15
Period of exposure in hr.	1	1¼	1	1¼	1	1¼	1	1¼	1	1¼	1	1¼	1	1¼	1	1¼	1	1¼	1	1¼	2	2½	2	2½
Number of survivors	51	50	30	30	32	34	30	30	15	20	20	20	22	38	40	40	29	36	40	40	12	14	15	15
% Mortality	54	50	0	0	47	44	0	0	47	37	0	0	45	37	0	0	35	28	0	0	63	46	0	0

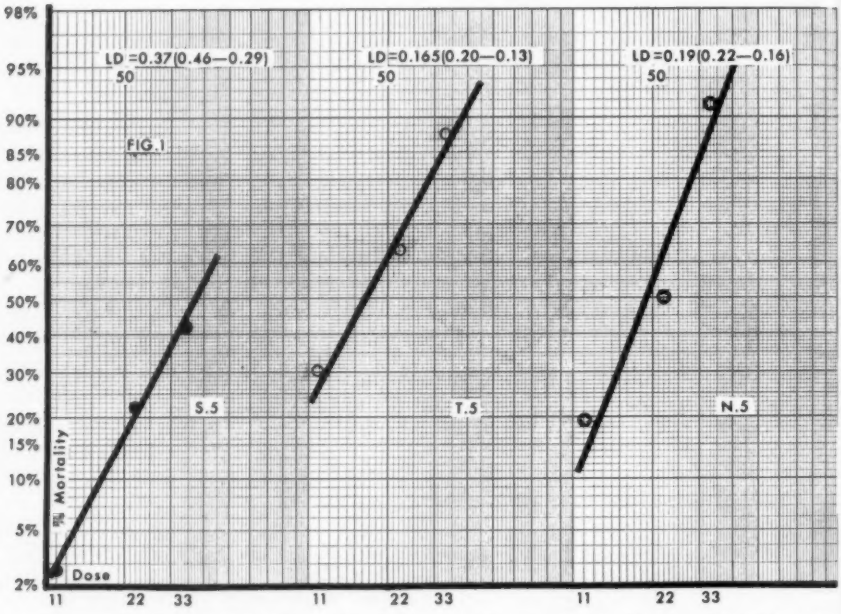

Fig. 1. Dose mortality data for the fifth generation weevils resolved graphically by the method of Litchfield and Wilcoxon on logarithm-probability paper. Dose scale repeated three times. LD_{50} (with fiducial limits in brackets) is given above each line.

The first test was done with fifth generation weevils and the second with sixth generation weevils.

The two tests were carried out by the same method. The tests were performed in three replicates on three different days. The first replicate comprised third-emergence group weevils of S_5, T_5 and N_5, the second replicate fourth-emergence group weevils and the third replicate fifth-emergence group weevils. Three doses of insecticide were used in the form of 1 ml. volumes of 11%, 22% and 33% concentrations. One ml. volumes were used as greater control over the dose was possible than with the 2 ml. volumes used for selection pressure. The three concentrations were applied to filter papers under standard conditions from three separate burettes. Weevils were exposed on the filter papers for 11½ hours at 22° ± 1°C. and R.H. 60-65%. The treatments were applied in each replicate in a random chronological sequence using a table of random numbers (Snedecor, 1956). Six males and six females were confined together on each filter paper in each replicate. A total of 324 weevils was used. After exposure, the weevils were placed in small jars with 30 gm. of wheat. Mortality counts were taken 7 days later. The results were analysed by the graphical method of Litchfield and Wilcoxon (1949) and are given in Figures 1 and 2.

It can be seen that after 5 generations of exposure to allethrin and piperonyl butoxide the S series weevils were 2.24 times less susceptible to the insecticide than the T series weevils and 1.95 times less susceptible than the N series weevils, both these differences in susceptibility being significant by a Chi squared test.

After six generations of exposure, the S series weevils were 2.30 times less susceptible than the T series weevils and 2.03 times less susceptible than the N

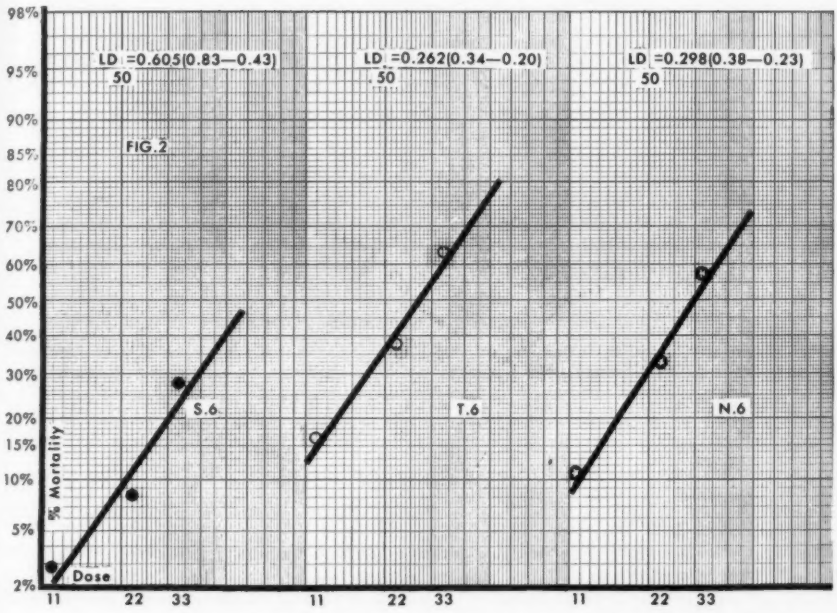

Fig. 2. Dose mortality data for the sixth generation weevils resolved graphically by the method of Litchfield and Wilcoxon on logarithm-probability paper. Dose scale repeated three times. LD_{50} (with fiducial limits in brackets) is given above each line.

series weevils, both these differences in susceptibility being significant by a Chi squared test.

The S_5, T_5 and N_5 were each respectively more susceptible than the S_6, T_6 and N_6.

Additional Observations

Weights of Weevils

Though male weevils appeared to be larger than female weevils, no statistically significant difference in weight was noted. There was no evidence that the insecticidal treatment selected heavier weevils.

Discussion and Conclusions

Selection at the LD_{50} for six generations resulted in weevils that were tolerant to the insecticide. As the slope of the regression line for the weevils exposed to insecticide did not change, it seems likely that the treated weevils exhibited "vigour tolerance". It seems unlikely that true resistance could have been selected in six generations.

In the two comparative tests, all the sixth generation weevils were less susceptible than the respective series in the fifth generation. It is felt that this was attributable more to heterogeneity of the biological material than to any irregularity in the carefully standardized technique. Perhaps if all weevils used in these experiments had been descended from a single pair, greater homogeneity in the biological material would have been obtained. The validity of the comparisons between the S, T and N series weevils was not affected as each comparative test was an entity in which each series was validly represented. In a

residual deposit method the dose of toxicant received by an insect depends to some extent on its locomotory activity on the toxic substrate. Moreover, in the present work, some of the weevils undoubtedly left the filter papers occasionally for perambulations on the confining glass. It seems then, in work of this kind, that the greater the exposure period of the insects to the toxic substrate the more homogeneous will be the resulting data: exposure period can usually be lengthened, without causing 100% mortalities, by lowering the toxicity of the substrate.

No adequate explanation for the finding that males were more susceptible than females is at present available. Other workers have observed similar differences (Bruce, 1950; Harrison, 1952, 1954; Pimentel, Schwardt and Dewey, 1953, 1954; Busvine and Khan, 1955).

Acknowledgments

We gladly use this opportunity to express our thanks to Drs. C. A. Atwood and W. E. Beckel of the Department of Zoology, University of Toronto, for valuable advice; to our colleague Dr. G. C. Ashton for advice on statistical procedure; and to Dr. W. E. Heming in whose Department the work was done.

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Taxonomy and Biology of *Pineus strobi* (Hartig) and *P. coloradensis* (Gillette) (Homoptera: Adelgidae)

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During 1958 a general infestation of *Pineus coloradensis* (Gillette) was observed on red or Norway pine, *Pinus resinosa* Ait. This insect is widely distributed throughout western United States where it attacks a number of pines. The Annand collection has a slide with specimens of *P. coloradensis* (Gillette) taken from red pine on the University of California campus dated February 10, 1925. However, there are few reports of any *Pineus* species attacking red pine in its natural range from the region of the Great Lakes to the Atlantic coast. Shenefelt and Benjamin (1955) have reported the white pine bark aphid or a closely related form on red pines in Wisconsin. Bean and Godwin (1955) also mentioned the presence of an unidentified species of *Pineus* on red pine.

At the beginning of the study it was found that *P. coloradensis* could not be easily separated from *P. strobi* (Hartig). This difficulty arose because collections from widely separated areas indicate a certain amount of intraspecific variation for both species, and secondly the taxonomic position of *P. strobi* is not clear. The confusion of *P. strobi* with certain other species is particularly evident when one deals with the apterous forms. Since it is usually impossible to collect winged sexupara, characters for separating the apterae are needed. This preliminary study is an attempt to clarify the identification of both species and to add to the knowledge of their biology.

General Methods

During 1958 and 1959 periodical collections were made from the needles and bark of white and red pines growing in the open and in the greenhouse. The insects were mounted according to the methods proposed by Hille Ris Lambers (1950). Very gentle or no treatment of the crawlers with KOH was necessary in order to prevent the loss of lightly pigmented plates on the thoracic shield. Drawings and measurements were made with the aid of a camera lucida and an eyepiece micrometer disc respectively.

Observations were made in the field and greenhouse on habits, host range and life cycle of both species. All transfer and host experiments were carried out in the greenhouse where both species were reared through a number of generations.

Pineus coloradensis (Gillette)

Morphology

Crawlers—The yellowish crawlers are slender in appearance (Fig. 1). The average length of 33 mounted specimens was .35 mm. with a range of .27-.46 mm. The average width was .17 mm. with a range of .11-.21 mm. No differences were noted between crawlers of the summer and winter forms.

Two pairs of plates are present on the head anterior to the ocelli.

The crawlers are close to the description of Annand (1928) with regard to the plates, but differ slightly in size. The pigmentation of the plates and areas around the setae is often rather light.

Adults—One of the best diagnostic characters concerns the shape and arrangement of the glandular facets on the cephalothoracic shield of the adult (Fig. 3). In general a number of the glands may be used although the facets that comprise the glands on the posterior part of the cephalothoracic shield tend to be

smaller. The gland best suited for comparison lies mesad to the three ocelli. The facets of the glands on *P. coloradensis* are circular and each facet appears to be separate from the next. There is no heavy netting around the facets or around the outer margin of the gland. The glands on the shield are raised or convex. The largest of the facets on the gland lying mesad to the ocelli is only slightly greater in area than an ocellus. Other characters are generally similar to those described by Annand.

The characteristics of the facets in *P. coloradensis* adults are essentially the same for both the winter or summer forms. However, the facets in the glands of the hiemoprogrediens or overwintering stage show a marked change between the last immature stage and the adult. The nymph has large glands that are practically indistinguishable from the glands of the mature *P. strobi* (Fig. 4) female as described later in this paper. The facets are angular with a dense pigmented netting around the facets but in the adult the glands again become typical of *P. coloradensis*. The antennae of the hiemoprogrediens are short and stubby when compared with that of the progrediens or summer form.

Measurements of the width and length of the last rostral segment were made for the purpose of comparison (Fig. 5). The average width of the last segment of the rostrum was taken at the widest part, usually at a point near the base. The average width was .035 mm. with a range of .023-.043 mm.

The gland areas of specimens of *P. coloradensis* collected in Connecticut generally had less pigmentation and smaller glands than those collected by Annand. However, as Annand has pointed out, the facet number may vary considerably even on a single individual. Nevertheless, the shape and arrangement of the glandular facets of specimens collected by Annand from yellow pine, *P. ponderosa* correspond with the facet arrangement of specimens collected from red pine in Connecticut.

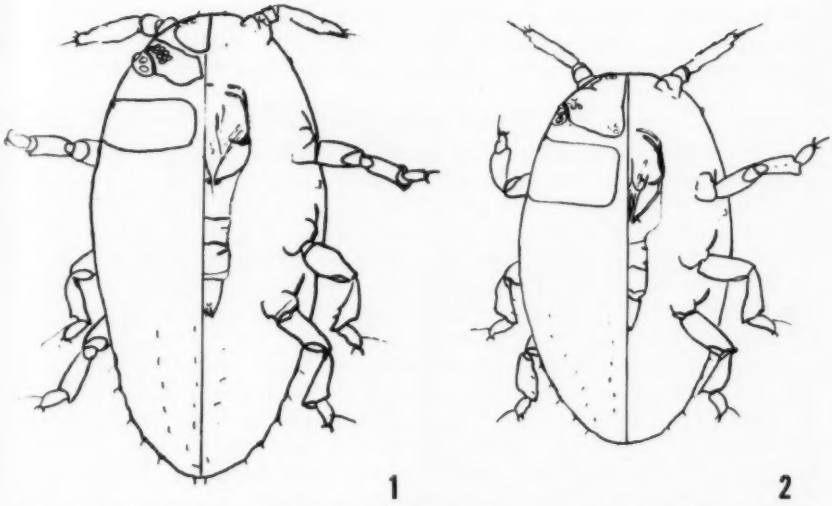
Biology

Observations on the life history of this species agree in part with those noted by Gillette (1907) and Annand (1928). The last stage nymphs hibernating on red pines were located most commonly near the bases of the needles either between the needles or between the sheath and the needles. No adults were found overwintering naturally although they are able to do so. This was shown by removing infested red pines from the greenhouse in December and placing them out-of-doors. The adults and the late stage nymphs survived; the eggs and early stage nymphs were killed.

No winged adults were found although systematic collections were made. In Colorado Gillette (1907) observed that about half of the brood hatching from eggs laid by overwintering females became winged. He noted that these individuals flew from pine but he was unable to trace them to an alternate host which he believed to be one of the spruces. Annand (1928) never observed winged forms during the study he made in California.

P. coloradensis is easily reared on red pines in the greenhouse and the needles soon become covered with the dense white secretion (Fig. 7). Such infestations were fatal to the small trees in the greenhouse. In nature the insects apparently do not become so numerous although infestations on young nursery trees may require treatment. Infestations are most noticeable during May when the spring brood is developing. During the summer months the infestation is much reduced.

P. coloradensis feeds only on the needles of a number of pines. In the greenhouse infestations on red pine build up until no more space is available.



Figs. 1-2. First stage nymphs. 1. *P. coloradensis* progrediens. 2. *P. strobi* progrediens.

The crawlers die on the needles and never settle on the bark. *P. coloradensis* can also be transferred to white pine growing in the greenhouse (Fig. 8). Here also the insects feed on the needles and not the bark. *P. coloradensis* does not reproduce as fast on white pine as on red pine.

P. coloradensis caused a type of feeding injury new to white pine needles which was not observed on red. New white pine needles often collapsed and died. Needles of the previous years' growth were not injured.

During cool damp weather, particularly from August through autumn, the secretion of *P. coloradensis* usually becomes covered with a dark olivaceous fungus that eventually causes the secretion to appear almost black. The fungus brings about a matting of the secretion into a firm mass which appears to prevent movement of the insects through or under it. High mortality occurs under these conditions. The fungus grows equally well on the secretion of *P. coloradensis* when the latter feeds on the needles of the white pine. The fungus is apparently not directly pathogenic to *P. coloradensis* although two or three specimens were found with the mycelia growing from them. Annand (1928) has noted the same type of fungus growth on the secretion of *P. coloradensis* during cool wet weather.

By comparison no fungus growth was seen on the secretion of the white pine bark aphid even when exposed to the same conditions of temperature and humidity. Pieces of fungus mat were placed in clumps of the *P. strobi* secretion but the fungus was unable to establish. In another test newly produced secretions of both species were placed side by side on damp paper in petri dishes along with strips of fungus-covered secretion. The fungus was unable to establish on the secretion of *P. strobi* but did so on that of *P. coloradensis*.

Hosts

Only red pine and pitch pine were found naturally infested with *P. coloradensis* in Connecticut. Results of transfer tests in the greenhouse were consistent with reports that this species has a wide host range (Annand (1928). It

was transferred and became established on the needles of eastern white pine, *Pinus strobus* L. (Fig. 8), pitch pine, *P. rigida* Mill., jack pine, *P. banksiana* Lamb., ponderosa pine, *P. ponderosa* Laws., and Scots pine, *P. sylvestris* L.

Pineus strobi (Hartig)

Although *P. strobi* was the first *Pineus* studied in this country, its taxonomic history has been much confused. Fitch (1859) named it *Coccus pinicorticis* and later Shimer (1869) placed this species in synonymy with *P. pinifoliae* (Fitch). Other workers including Osborn (1879) and Storment (1885) confused *P. strobi* with *P. pinifoliae* as well as with other species found on the needles. This was not corrected until Patch (1909) reestablished them as two separate species. As a result certain early reports contain many unreliable observations on hosts, habits and life history of *P. strobi.*

The principal taxonomic studies on *P. strobi* have been made in Europe. Börner (1909) advanced suitable characters for separation of *P. strobi* from other European forms. Marchal (1913) agreed with the work of Börner and contributed to the biology of *P. strobi.* Annand (1928) has pointed out that the true identity of the American forms of *P. strobi* was not clear. His figures and descriptions are not comprehensive enough to separate *P. strobi* from closely related species. It appears as though some of his material was quite different from that examined by Börner. Annand mentioned the possibility that *P. strobi* (Hartig) might not be synonymous with *P. pinicorticis* Fitch.

Morphology

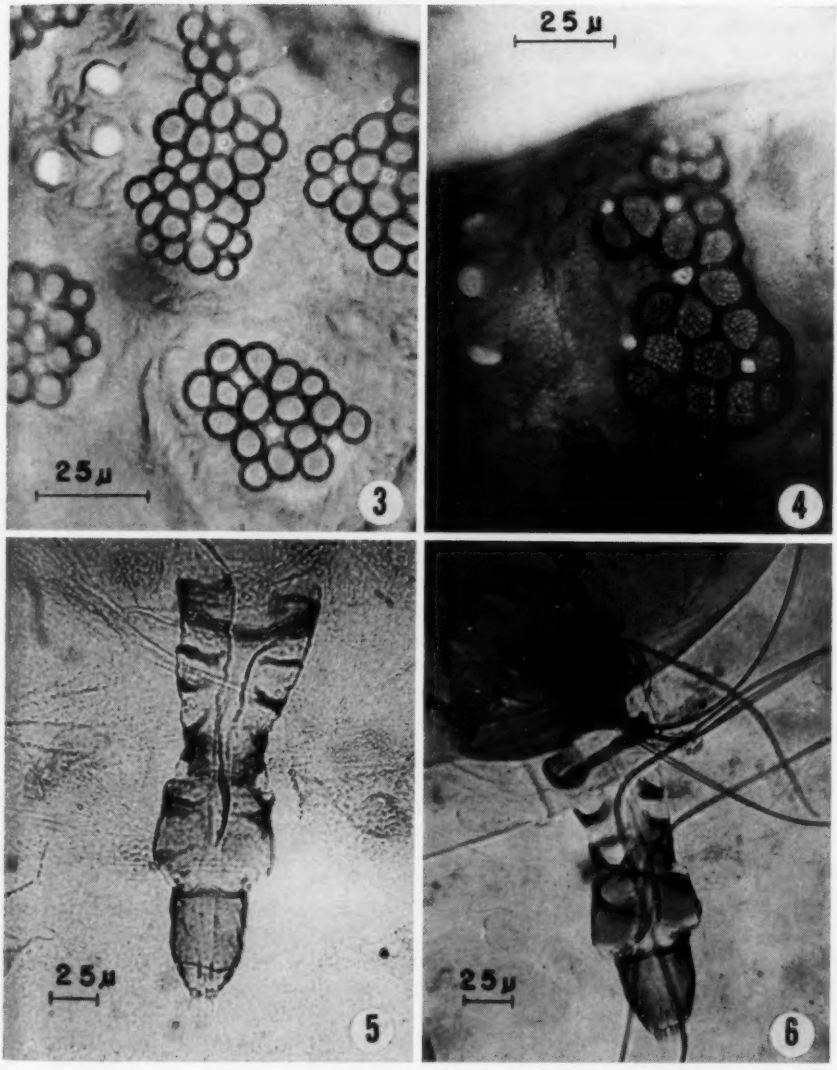
Crawlers — These are yellow and quite broad in outline (Fig. 2). The average length of 33 mounted specimens is .34 mm. with a range of .27 to .39 mm. The average width was .20 mm. with a range of .12 to .19 mm. There is a pair of plates on the head and each plate is partially separated by a slit that runs into it near the base of the antennae. The distribution of the dorsal plates and the general appearance of *P. strobi* crawlers agree with the description given by Börner for the European forms.

Adults — The facts that comprise the glands are quite angular in shape giving the glands a netted appearance (Fig. 4). The facets are separated by a pigmented band that is heavier around the outside margin of the gland than it is between the facets. The larger facets of the gland mesad to the ocelli have about twice the area of a single ocellus.

Although there appears to be considerable variation in the number of facets between the progrediens and the hiemoprogrediens, the other glandular characteristics mentioned above remain the same in the adults. The hiemoprogrediens have shorter antennae than do the progrediens.

The average width of the last rostral segment of *P. strobi* was .033 mm. with a range of .028 to .043 mm. The average length was .038 mm. with a range of .033 to .051 mm.

The characteristics of the glands described above are closer to the descriptions of *P. strobi* by Börner (1908) and Marchal (1913) than those of Annand (1928). Börner noted that the individual facets formed a close- or wide-meshed net. Marchal stated that the glandular facets of *P. strobi* appeared as a dark polygonal netting instead of being separate and individual as was the case with another species *P. pini* (L.). The figures and descriptions of the glandular facets by Annand differ from my material and from the descriptions of Börner and Marchal. In some of the material examined by Annand the facets of the glands



Figs. 3-6. 3. Ocelli and arrangement of facets in glands of *P. coloradensis* adult hiemoprogrediens. 4. Ocelli and gland of *P. strobi* adult hiemoprogrediens. 5. Rostrum of *P. coloradensis* adult hiemoprogrediens. 6. Rostrum of *P. strobi* adult hiemoprogrediens.

are less angular, more loosely grouped into areas and apparently are not contained in a heavy pigmented netting.

Examination of specimens collected from widely separated areas may show whether these are variations of the same species or of different species. Certainly a number of specimens in the collection at the National Museum in Washington show considerable variation from the typical forms.

Biology

The pine bark aphid, *P. strobi*, is commonly encountered feeding on the bark of the eastern white pine, *P. strobus* L. Infestations of the insect are easily observed from the masses of white cottony secretion covering them as they congregate on the undersides of the branches and protected parts of the trunk.

From collections made during February of both years, it is apparent that *P. strobi* overwinters in the late immature stage. No adults were found. However, *P. strobi* adults are able to overwinter on trees removed from the greenhouse during December.

Attempts to collect winged forms of *P. strobi* also failed during the two-year period. Two pupae were found during this time. It appears that winged forms are abundant only during certain years. For example, records show that a large number of winged forms were collected from white pine by B. H. Walden on June 3, 1914.

Little is known about the habits of these winged sexuparae. In Europe Marchal (1913) found that the sexuparae could fly to black spruce, *Picea mariana* (Mill.) B.S.P., which was growing as an ornamental. He found that the sexuparae laid eggs from which only female sexuales hatched. These died without reproducing. It is not known whether this is the case in this country where the black spruce is endemic.

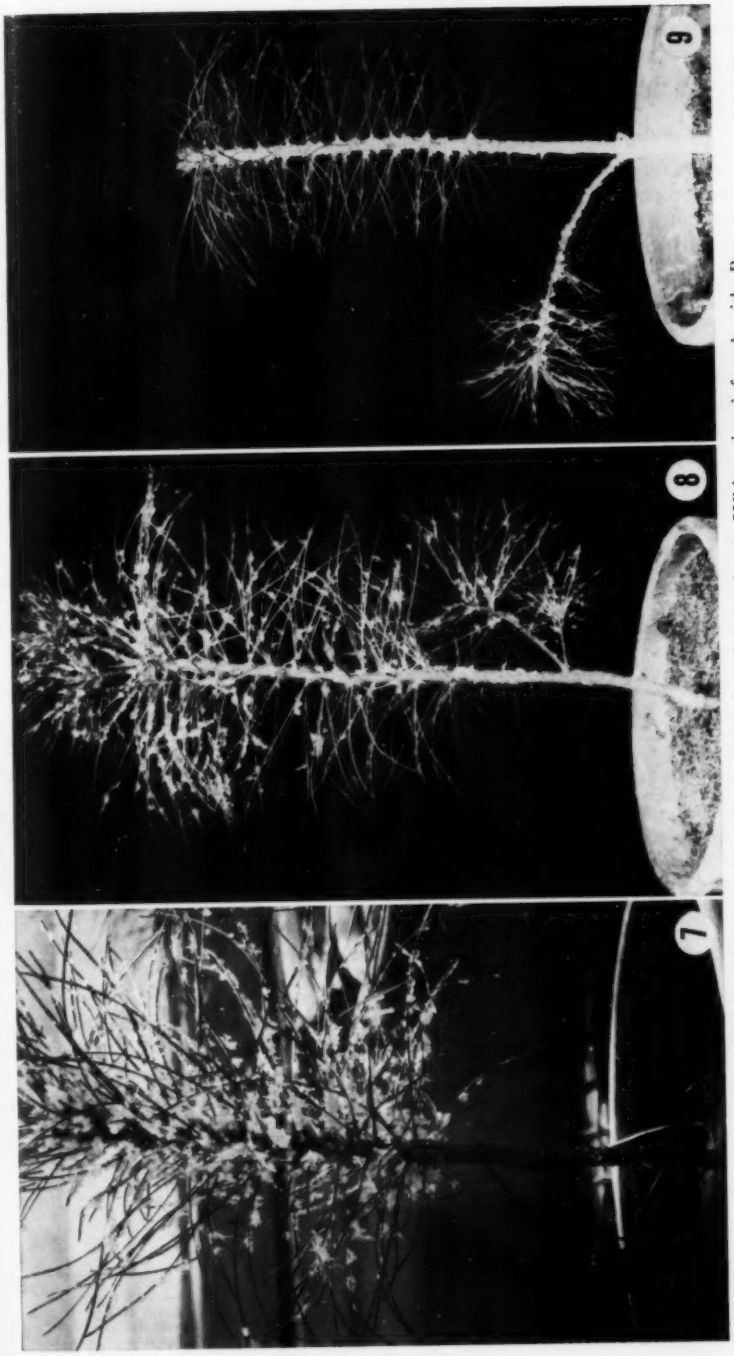
The pine bark aphid does not attack the needles of white pine. The bark of the pine in Fig. 9 is representative of a number of small pines that had the bark completely covered with the insects and their secretion. Hundreds of the crawlers died on the surface of the secretion but none settled on the needles. This species readily settles around the bases of the needles but the mouthparts are inserted into the bark and not in the needles.

P. strobi did not establish on red pine. A number of nymphs from white pine settled on red pine bark but none of them matured.

Separation of the Species

The crawlers of the two species are distinguished by the position and number of the plates on the cephalothorax (Figs. 1 and 2). In addition to this the crawlers of *P. coloradensis* are proportionately more slender in their body form. Measurements were made of 33 individuals from each species and the ratios of length to width were compared statistically using a t-test. The test indicated that there was a significant difference between the crawlers at the 1% level.

The apterous adults can be distinguished by the character of the glandular facets. In *P. coloradensis* the facets of the gland are circular and each has a separate margin. The larger facets on the gland lying mesad to the ocelli are only slightly greater in area than an ocellus. In *P. strobi* the facets are angular and each is separated by a dark pigmented netting which tends to be heaviest on the outer margin of the gland (Figs. 3 and 4). The larger facets of the gland mesad to the ocelli have about twice the area of a single ocellus.



Figs. 7-9. 7. Red pine infested with *P. coloradensis*. 8. White pine infested with *P. coloradensis*. 9. White pine with bark completely covered with the secretion of *P. strobi*.

The measurements of the width and length of the last rostral segment for the two species were compared. The use of a t-test indicated the widths of the two species were not significantly different but that the last rostral segment of *P. coloradensis* is significantly longer than that of *P. strobi* at the 1% level.

P. coloradensis is a needle feeder on a variety of pines. *P. strobi* settles on the bark of white pine. It did not establish on red pine.

In wet cool weather a fungus grows on the secretion of *P. coloradensis* but does not do so on the secretion of *P. strobi.*

Summary

The apterous forms of *P. strobi* (Hartig) and *P. coloradensis* (Gillette) have been difficult to distinguish. Characters of the apterae are described that clarify the taxonomic position of *P. strobi* crawlers and adults and allow separation of the two species. Observations were made on the biology and host range of both species. *P. coloradensis* is a needle feeder on a number of pines. *P. strobi* is a bark feeder and in nature probably feeds only on white pine, *Pinus strobus* L. During wet cool weather a fungus grew on the secretion of *P. coloradensis,* but not on the secretion of *P. strobi.*

Acknowledgments

I wish to thank Miss Louise M. Russell, Entomology Research Division, U.S.D.A., Washington, for valuable criticism and the loan of slide material and Dr. James B. Kring of this station for many helpful suggestions.

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An Evaluation of Some Larval Growth Criteria[1] in European Pine Shoot Moth Larvae

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In recent ecological studies on the European pine shoot moth, (*Rhyacionia buoliana* (Schiff.)), where a major objective was to evaluate the influence of different hosts on oviposition preference, larval mortality, insect size, rate of development, and sex ratio, the inadequacy of conventional growth measurements was much too apparent. There was a need to document relatively small differences in larval size and rate of growth on several hosts or from one stand to another. Measurements which showed growth but not weight or volume losses have limited value where the insect under study has a long non-feeding period. Such measurements as body length, and especially head capsule width, obviously belonged in this category. On the other hand, it was felt that dry weight measurements would show both gain and loss. Further, a volume estimate (or body index) would be even more useful, if one could be devised which bore a linear relationship to dry weight. Such an index, while it might involve more than one measurement, nevertheless could be made without destroying the larvae.

Materials and Methods

In order to demonstrate the relationship between the various body measurements and to determine which measurements might bear the strongest linear relationship to dry weight, the correlation between dry weight, head capsule width and body length was studied. Twenty-seven larval collections were made at different dates throughout the season from red pine (*Pinus resinosa* Ait.). The insects were killed in Peterson's (1948) KAAD solution and preserved in 95 per cent alcohol. From each of these collections, ten insects were selected at random for measurements on each individual of (1) head capsule width, (2) body length, and (3) dry weight. The limits of accuracy for each measurement were (1) head capsule to the nearest .03 mm.; (2) body length to the nearest .2 mm.; and (3) dry weight to the nearest .02 mg.

It was felt that since both head capsule width and body length are linear measurements, a volumetric measurement might correlate more closely with changes in dry weight. A simple volumetric estimate or "body index" was arrived at by combining the two linear measurements (1) and (2). The estimate consisted of taking the square of one-half the head capsule width and multiplying this by the body length. Then, if the body index were multiplied by the constant 3.1416, an estimate of the insect's total volume would be obtained expressed as cubic millimeters. The procedure, in effect, entails computing the volume of a cylinder; with the diameter equal to the head capsule width and the height equal to the body length. Since 3.1416 is a constant for all observations, it was not necessary to complete the multiplication for statistical analysis.

Results

Figure 1 shows mean value of four parameters throughout the year; dry weight, head capsule width, body length, and the computed body index. It is apparent from the graph that increases in head capsule width closely approximate increases in dry weight during the early period of maximum growth, but that this

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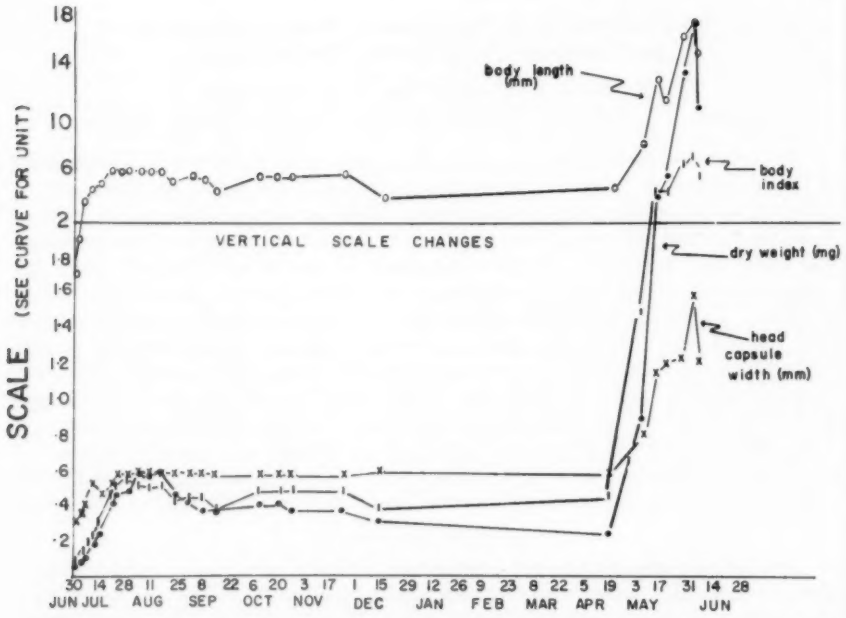

Fig. 1. Mean dry weight, mean head capsule width, mean body length and mean body index plotted against date of collections. Body index was computed by multiplying body length times one-half of the head capsule width squared.

measurement is completely insensitive to negative growth or losses in dry weight and to growth taking place during the ultimate instar. It can be seen, on the other hand, that body index and length are more sensitive in expressing increases and decreases in dry weight.

To put the interpretation of this graph on a statistical basis, a multiple correlation was made of the two linear body measurements and dry weight; while a separate correlation analysis was made of the body index and dry weight. It was not considered advisable to include the body index in the multiple correlation analysis, since it was a function of the two measured variables and might confuse interpretation.

In this analysis larvae collected throughout the year were considered as a continuous series. This method results in having measurements on individuals which possessed extreme differences in body dimensions. Because of these extremes in sizes of individuals it is to be expected that the correlations will be more pronounced than if a single large collection were taken, provided the accuracy of the measurements remain constant. Since the purpose of the study was to evaluate which criteria best expressed growth it was thought advisable to use a technique which would consider all sizes occurring within the population throughout its development.

The multiple correlation coefficient (Ry. x_1x_2, where y = dry weight, x_1 = head capsule width, x_2 = body length) equalled .870 and it can be stated that $(.870)^2$ or .7573 per cent of the variation in dry weight could be eliminated if head capsule width and body length were held constant. However, if head capsule width and body length are used to compute a body index (x_3), and a zero order correlation between body index and dry weight is obtained (r_{yx_3}), a cor-

relation of .923 is forthcoming. This correlation can account for 85 per cent of the variation in dry weight by holding the body index constant.

Obviously, there are advantages in converting head capsule and body length measurements to this index. It can account for 10 per cent more variation in dry weight than does the multiple correlation coefficient. The difference is significant at the 1 per cent level, using Fischer's method for the transformation of "r" to "z" as described by Snedecor (1957, p. 178).

It is of interest to compare the multiple correlation coefficient ($Ry.\ x_1x_2$) to the zero order correlation coefficients of dry weight to head capsule width ($^{r}yx_1$), which equals .775; and dry weight to body length ($^{r}yx_2$), which equals .870. As stated before, in a multiple correlation head capsule width and body length measurements can account for .7573 per cent of the variation in dry weight but the zero order correlation of dry weight to body length ($^{r}xy_2$) accounts for .7569 per cent. By making all of the measurements on head capsule width and computing the multiple correlation coefficient, only an additional .0004 per cent of the variance in dry weight is accounted for. It can be considered from this that practically all of the variance in dry weight which can be accounted for in head capsule width can also be accounted for in body length. Practically nothing has been gained in making head capsule measurements unless the body index is computed or some other appropriate transformation is made.

By establishing 95 per cent confidence limits for the prediction of mean dry weight from either head capsule width, body length, or body index it was possible to estimate the sample size needed to predict the mean dry weight within 0.1 mg. This estimated sample size indicates in a different way the relative value of the various measurements in the prediction of dry weight. It would take an estimated sample size of 119 head capsule widths to estimate within .1 mg., with 95 per cent confidence, the mean dry weight of insects of average head capsule width. To make this same estimate of dry weight would require 72 body lengths or 44 body index values.

Summary

While it should be acknowledged that head capsule measurements have been made on many different insects, this study demonstrates that for European pine shoot moth larvae, they are inferior to volume (i.e., body index) and/or dry weight measurements. Unless there are compelling reasons why a particular instar, or the number of instars should be recognized, it must be concluded that the volume index and even body length more accurately reflect seasonal changes in dry weight. The usefulness of head capsule widths in indicating larval instars appear to be of limited value (Beck 1950). In this study only the dry weight measurements were sensitive enough to show small losses in weight. Of those values used to predict dry weight, the computed body index was the most satisfactory. Measurements of head capsule width in this study could only be justified if they were used to compute the body index, since body length alone could predict dry weight better than head cupsule width, and at least as well as the multiple correlation involving both body length and head capsule width.

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A Pneumatic Laboratory Cage for Thysanoptera or other Arthropoda[1]

By J. A. George

Testing arthropods for their ability to transmit plant viruses depends on a satisfactory means of confining test specimens on plant hosts while excluding all other arthropods. This can be difficult with small, active insects such as the Thysanoptera. Screen or cloth capable of confining them must be of such fine mesh that adequate ventilation is prevented and condensation becomes a problem.

A simple but satisfactory means of caging all stages of Thysanoptera, as well as other Arthropoda, was devised by using polyethylene bags ventilated by compressed air (Fig. 1). Bags 5 x 3 x 15 inches stretch over and fit snugly around the outside of a five-inch clay flower pot or stendor glass. The bag is inflated and maintained upright by compressed air. A screened opening enables sufficient ventilation to prevent condensation when external conditions do not vary greatly.

Among the advantages of this type of cage is that it prevents escape of small arthropods and contamination by others from outside. The contents are also protected from toxic vapours and dusts. The flexibility and transparency of polyethylene permits observation of caged plants and arthropods from almost all angles and the bag can be manipulated to examine leaves with a hand lens, or to rearrange plants, without opening the cage. Bags can be made of any desired shape to accommodate test plants. Potted cherries up to three feet high have been caged by removing the closed end of a bag and sealing it, end to end, to another. The bags are cheap and disposable.

Construction requires only a few minutes per cage. Near the closed end of the bag a ¼ inch hole is punched with a cork borer and is covered with a ¾ inch circle of cloth with a mesh fine enough to prevent the escape of the arthropods to be caged. A 1½ inch square of polyethylene, with a central ¼ inch hole, is placed over the cloth which is then sealed between the two layers of polyethylene by applying moderate heat and pressure through metal foil.

An air inlet is provided in the wall of the bag about three inches from its open end. A two-inch length of light plastic tubing (a Spinco lusteriod centrifuge tube 0.328 inches in diameter with the bottom cut off) is inserted through a ¼ inch hole in the bag and held in place by short lengths of thick walled (3/16 inches or more) rubber tubing forced over its ends. The inlet tube is connected to a compressed air line with ¼ inch rubber tubing. A series of cages can be operated simultaneously by attaching them to ¼ inch outlets on a manifold of one inch copper tubing.

Air from the compressor is filtered through an "air purifier"* which traps oil mist and dust and some moisture. Air flow into the bags is maintained at a constant level and regulated at a rate high enough to keep the bags inflated and free from condensation by a pressure reducing valve adjustable from 0-5 p.s.i.

Insects are introduced or extracted by an aspirator through the inlet tube. The plants are watered either through the inlet tubes or from below by placing the pots in saucers.

Air flow through the bags enables the cages to be maintained free of internal condensation when they are kept in a basement room under fluorescent lights

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*Koby Air Purifier and Flow Equalizer: The Koby Corporation, 85 Joy Street, Boston 14, Mass., U.S.A.

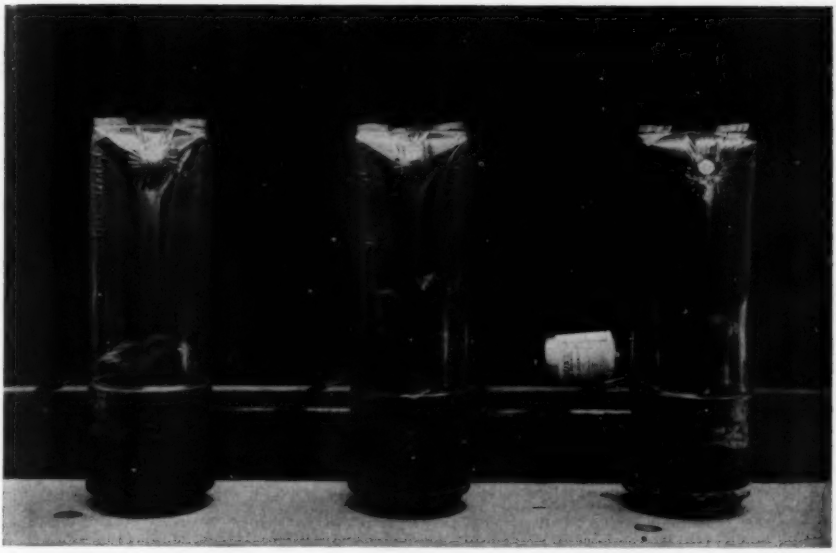

Fig. 1. Polyethylene bags used as pneumatic cages for Thysanoptera. The bags are maintained upright and ventilated by compressed air. Left, cucumber; centre, Montmorency cherry; right, tomato.

and fairly constant temperature. Operation in the greenhouse, however, is not always satisfactory because of the wide variations in temperature and direct sunlight.

In plant virus transmission tests with various species of Thysanoptera, Cicadellidae and Aphidae during the past year there has been no indication that polyethylene is toxic to plants or insects.

This method of caging has enabled accurate testing of the ability of various species of Thysanoptera to transmit virus diseases. It has also been of value with aphids by facilitating the rearing of virus-free, parasite-free homogenous colonies from single specimens. It has been found to be more satisfactory than lantern glass cages in caging the six-spotted leafhopper, *Macrosteles fascifrons* (Stål), for virus transmission tests. The characteristics of this type of cage of value in studies with vectors of plant viruses may also be of advantage in other entomological research, especially with small arthropods.

Summary

A means of caging small Arthropoda with polyethylene bags, maintained upright and ventilated by compressed air, is described.

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A New Nearctic Genus of Miridae, with Notes on *Diaphnidia* Uhler 1895 and *Brachynotocoris* Reuter 1880 (Hemiptera)

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A study of the genus *Diaphnidia* Uhler showed that *D. debilis* Uhler, the type of the genus, was markedly different and not congeneric with the five other species hitherto included. A new genus, *Diaphnocoris*, is described for four of these: *pellucida* Uhl. (type), *capitata* Van Duzee, *crockeri* Van Duzee, and *provancheri* Burque; the fifth species, *heidemanni* Knight, is considered to belong to *Brachynotocoris* Reuter. Following are descriptions of the three genera of this group as now considered.

Diaphnidia Uhler, 1895

Type species of genus – *Diaphnidia debilis* Uhler, 1895, designated by Carvalho (1952).

Length, 5.5 mm.; width, 1.5 mm. Head width, 3.08 mm., vertex, 1.54 mm., head pale green, carina absent, vertex slightly grooved at middle, with a little callus each side between the eyes. Antenna: I, 0.49 mm., II, 1.78 mm., pale yellow; III and IV missing. Rostrum 1.08 mm. long, reaching beyond anterior coxae. Pronotum 0.49 mm. long, 1.01 mm. wide, yellowish, gently sloping; calli somewhat raised with a shallow depression behind; basal margin convex. Hemelytra pale green; pubescence pale, semi-erect, veins on membrane green. Abdomen and legs greenish. Male genitalia as illustrated (Figs. 2, 3), female not available.

Lectotype in the United States National Museum, Washington, D.C., bearing these data: Colorado, 1342, det. Uhler, C. F. Baker Collection.

Diaphnocoris new genus

Type species of genus – *Diaphnidia pellucida* Uhler, 1895.

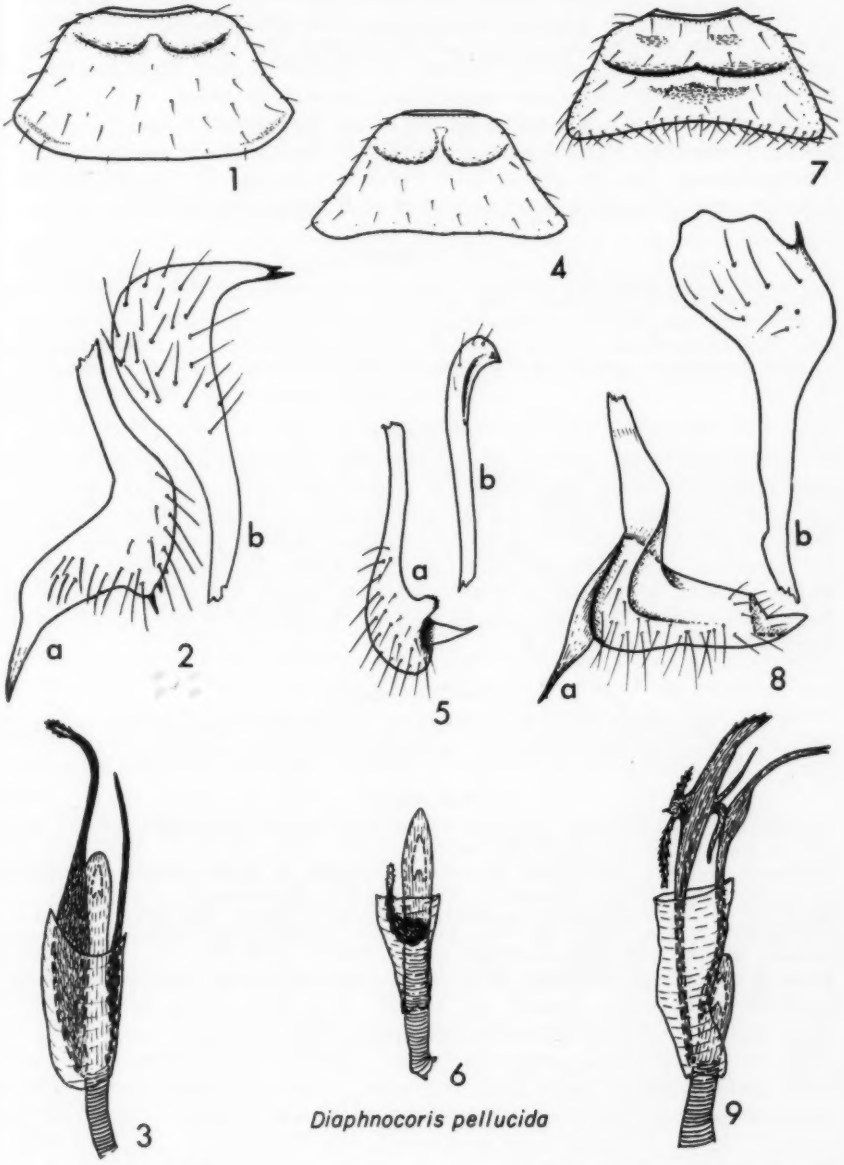
Head short and blunt; tylus prominent; rostrum reaching middle coxae or beyond; eyes large, somewhat removed forward from the posterior margin of head; carina at vertex present or obsolete, area in front somewhat depressed. Pronotum trapeziform, smooth, anterior angles gently rounded, lateral margins rounded or angular towards base; calli slightly raised, with shallow depression behind; basal margin sinuate (Fig. 4). Hemelytra pale green and shiny, smooth, nearly parallel sided; pubescence pale, semi-erect. Legs pale green. Genitalia as illustrated (Figs. 5, 6).

The four known species in this genus are: *pellucida* (Uhl.), *capitata* (Van D.), *provancheri* (Burque), and *crockeri* (Van D.); the latter species not examined.

Brachynotocoris Reuter, 1880

Type species of genus – *Brachynotocoris puncticornis* Reuter, 1880, designated by Carvalho (1952).

Length 4.3 – 4.8 mm. Green, shining. First antennal segment beneath at apex with a black spot, sometimes obsolete; third antennal segment longer than second. Rostrum very short, reaching slightly beyond anterior coxae, and shorter than width of head. Pronotum short and flat, with a distinct transverse impression behind calli. Pubescence on hemelytra pale, dense, semi-erect; veins of membrane greenish. Abdomen and legs green.



Figs. 1-9. 1-3, *Diaphnidia debilis* Uhl.; 4-6, *Diaphnocoris pellucida* (Uhl.); 7-9, *Brachynotocoris heidemanni* (Kngt.); 1, 4, 7, pronota; 2, 5, 8, right and left claspers; 3, 6, 9, vesicae; a, left clasper; b, right clasper.

The long third antennal segment and the short rostrum of *Diaphnidia heidemanni* Kngt. place the species in this genus. Also, the genitalia of *heidemanni* (Figs. 8, 9) are very similar to those of *puncticornis* Reut. illustrated by Seidenstücker (1954), and suggest that the two are closely related. Thus *heidemanni* becomes *Brachynotocoris heidemanni* (Kngt.), new combination.

B. puncticornis is known from the Palearctic region, where two other species, *parvinotum* (Lindberg) and *viticinus* Seidenstücker are also recognized. The species are known to feed on *Vitex* and *Fraxinus*. In North America, *Fraxinus excelsior* is given as the host plant of *B. heidemanni* (Kngt.)

Key to Genera

1. Second antennal segment shorter than third ..... *Brachynotocoris* Reut.
   Second antennal segment longer than third 2
2. Rostrum reaching middle of mesosternum; pronotum convex at base (Fig. 1) ..... *Diaphnidia* Uhl.
   Rostrum reaching middle coxae or beyond; pronotum concave or sinuate at base (Fig. 4) ..... *Diaphnocoris* n. gen.

Summary

Diaphnidia Uhler, 1895, is divided into two. The restricted genus contains only *debilis* Uhl., while *Diaphnocoris* n. gen., is erected for *pellucida* Uhl., *capitata* Van D., *crockeri* Van D., and *provancheri* Bur.; *heidemanni* Kngt. is assigned to *Brachynotocoris* Reut. Male genitalia of species belonging to the three genera are illustrated. *D. debilis* is known only from Colorado, *Diaphnocoris* spp. are transcontinental in temperate North America, except for *crockeri* which is known only from Galapagos Islands, while *B. heidemanni* is known only from Maryland and Washington, D.C.

Acknowledgments

I wish to extend my sincere thanks to Mr. D. M. Weisman, United States National Museum, Washington, for lending specimens for study.

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Further Hymenopterous Parasites Newly Recorded from the Armyworm, *Pseudaletia unipuncta* (Haw.) (Lepidoptera: Noctuidae)

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The author (1959) reported on four species of Hymenoptera that had not been previously recorded as parasites of the armyworm, *Pseudaletia unipuncta* (Haw.). During further studies at Ottawa four more new records were obtained: Three species were primary parasites, namely, *Netelia sayi* (Cush.) (Ichneumonidae), *Nepiera marginata* (Prov.) (Ichneumonidae), and *Microplitis alaskensis* Ashm. (Braconidae); and one species, *Catolaccus cyanoideus* Burks (Pteromalidae), was a secondary parasite. *N. marginata* and *M. alaskensis* were also reared from larvae collected at Kapuskasing, Ontario.

Larvae of *N. sayi*, an ectoparasite, developed on sixth-instar larvae in August, 1958, and July, 1959. Of 13 larvae bearing eggs of *N. sayi*, 11 were in the sixth instar and two in the fifth; there was one egg per larva on the dorsolateral margin of the pro- or meso-thorax. Eggs laid on fifth-instar larvae remained intact on the host when the latter moulted, being anchored to the host body internally by means of a petiole (Vance, 1927). The eggs hatched when the sixth-instar larvae were in the prepupal stage and just beginning to show signs of transformation; development of the host was arrested when the parasite began to feed. The parasite fed for about eight days, consuming all but the skin and head capsule of the host, and spun its cocoon in the earthen cell of the host. The adults emerged in about 23 days after the cocoon was spun. *N. sayi* has been recorded as a parasite of the noctuids *Graphiphora badinodis* Grote and the corn earworm, *Heliothis zea* (Boddie); in North America it is found from the Atlantic to 100° west in the Transition and Upper Austral zones and Mexico (Townes and Townes, 1951).

Nepiera marginata was reared from third-, fourth-, and fifth-instar larvae in August, 1958, and July, 1959. Of 55 parasitized larvae 53 were in the fourth instar. The host was active until just before the mature parasite larva emerged; the host came to rest on a blade of grass or other object and the parasite chewed its way through the caudal end and spun its cocoon nearby. The exuviae and head capsule were the only remains of the host and these were usually loosely attached to one end of the parasite cocoon. The adults emerged in about seven days after the cocoon was spun. Wood and Neilson (1956, 1957) recorded *N. marginata* as a parasite of two noctuids in New Brunswick: the black army cutworm, *Actebia fennica* (Tausch.); and *Graphiphora smithi* (Snell.). Walkley (1958) listed a third host, *Macrobotys pertextalis* (Led.) (Pyraustidae). This species has been recorded also from Ontario and Quebec (Townes and Townes, 1951).

In July, 1959, *Microplitis alaskensis* was reared from 20 larvae, 10 in the fourth instar and 10 in the fifth. The parasite larva emerged from the host through a hole chewed in the lateral surface of either the fifth or the sixth abdominal tergite and spun its cocoon nearby. The adults emerged in six to nine days after the cocoon was spun. The host died within 24 hours after the parasite larva emerged but moved about rather sluggishly during the early part of this period. In North America this species has been recorded from Alaska, Canada, and the United

States as far south as Kansas and is known to parasitize three other noctuids: *Dargida procincta* (Grote); the alfalfa looper, *Autographa californica* (Speyer); and *Plusia* sp. (Muesebeck and Walkley, 1951).

Catolaccus cyanoideus, a secondary parasite of Lepidoptera (Burks, 1954), emerged from the cocoon of a primary parasite that had been reared from a fourth-instar larva of the armyworm in July, 1958. The cocoon of the primary parasite appeared to be identical to that of *Campoletis oxylus* (Cress.). In the United States, *C. cyanoideus* has been recorded from Maine and Massachusetts and west to Michigan and Iowa (Burks, 1958).

Acknowledgments

The author wishes to thank Mr. G. S. Walley, Dr. W. R. M. Mason, and Dr. O. Peck of the Entomology Research Institute, Ottawa, for identifying the four species of parasites.

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(Received July 22, 1960)

A Note on *Hoplitis producta* (Cress.) in Wisconsin (Hymenoptera: Megachilidae)

By J. T. MEDLER[1]

The nesting biology of *Hoplitis producta* has been reported by several authors, as the species is a common and widely distributed bee in North America east of the Rocky Mountains. Additional records, which have been obtained in connection with trap-nest research on bees and wasps in Wisconsin, are provided to supplement the previous reports.

The nests were found in the pith at the butt ends of sumac stick trap-nests. A nest could be recognized readily because the 3 mm. plug that closed the burrow had a more solid texture and a darker color than the surrounding pith at the end of the stick. Rau (1928) found nests in tunnels of elder, sumac or rose stems but could not ascertain whether the bee excavated its own burrows or utilized burrows left by other twig-dwellers. Fischer (1955) stated that the female almost invariably excavated its own burrow. In Wisconsin, freshly cut sumac sticks were placed in the field in the spring; therefore, each of the following records represents a nest in a burrow excavated by the foundress bee.

The contents of twenty-four nests collected in northern Wisconsin in 1955 and 1958 were reared in the laboratory. The cells were placed singly in glass vials and numbered so that the specimens reared in the incubator could be assigned to their proper sequence in the nest. Representative data (Table I) show females preceding males in the cell sequence, except in nest 12 where a female occurred between males. Several nests contained all females, but none contained all males. The data suggest that a sex ratio of 1:1 probably exists in Wisconsin rather than a ratio of two males to one female as reported in Colorado by Hicks (1923).

The length of pith available for burrowing in the butt of the trap stick was limited to 60-30 mm. and this may have been responsible for the maximum number of six cells. In several nests the burrows had been extended through the pith into the drilled out hole in the stick. In these cases the bee had plugged the bottom of her burrow before proceeding with provisioning the first cell. Studies could be conducted with undrilled sumac trap sticks to obtain information on the burrowing habits of this species and on the maximum number of cells produced by individual bees.

A typical nest consisted of a linear series of cells separated by partitions, an empty vestibule and an outer plug. The empty vestibule between the last cell partition and the outer plug is a feature previously described by Rau (1928). The plugs and partitions are made from masticated green leaf matter. Graenicher (1905) observed a foundress obtaining leaf material from wild strawberry, *Fragaria virginiana* Duch. The pulp is compressed into a disc that becomes almost impenetrable when dry. According to Rau (1928) the emerging bee cuts away the pith at the sides of the disc to escape, and in the process of escaping from their secure imprisonment more than half of the bees die.

Measurements on 50 cells gave an average cell length of 7.76 $\pm$ 1.1 mm., range 6 to 10 mm. The mean length of the vestibule was 14.4 mm., ranging from 5 to 25 mm., and that of the outer plug was 6.2 mm. The outer plug consisted of three to eight layers, each about 1 mm. thick. All partitions in the nests

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TABLE I
Rearing Record of *Heplitis producta* (Cress.) from sumac, showing sex of emerging bees, cell sequence, and parasitism.

Nest Number	County and Year	Burrow length mm.	Cell number					
			1	2	3	4	5	6
1	Washburn, 1958	37	♀	♀				
2	Ashland, 1955	30	S1 ♂	♀				
3	Washburn, 1958	41	♀	♀	♀			
4	Washburn, 1958	57	♀	♀	♂			
5	Ashland, 1955	56	♀	♀	S1 ♂			
6	Washburn, 1958	52	*	♀	♀	♂		
7	Bayfield, 1955	61	*	♀	♂	Mc		
8	Bayfield, 1955	44	♀	♂	♂	La ♂		
9	Polk, 1958	50	♀	♀	♀	♂	♂	
10	Bayfield, 1955	71	Mc	♀	♀	♀	Mc	
11	Bayfield, 1955	65	S2 ♀	♀	S2 ♀	Mc	S2 ♂	
12	Bayfield, 1955	57	†	♂	♂	♀	♂	♂
13	Bayfield, 1955	62	♀	†	♂	♂	♂	♂

*= Full grown larva crushed when nest opened; † = larva died during rearing; La = *Leucospis affinis* Say; Mc = *Melittobia chalybii* Ashm.; S1 = *Stelis labiata* Provancher; S2 = *Stelis lateralis* Cresson.

appeared as single layers and were ½ - 1 mm. thick. Rau (1928) described each partition as comprised of two layers each about ⅛ inch thick, close together but separate, one forming the roof of one cell and the other the floor of the cell above. He also found much irregularity in the dimensions of both cells and partitions. The Wisconsin nests had cells of fairly uniform length but there was considerable variation in the length of the vestibule. This is to be expected, as the bee placed a plug at the burrow entrance, and the length of the vestibule was, therefore, determined by the depth of the burrow and the number of cells, both of which were variable. It should be mentioned that there is some difficulty in determining the thickness of a partition as the fecal pellets of the larvae are pressed against the cell cap, forming a distinctive ring.

The larvae of *H. producta* were parasitized by *Leucospis affinis* Say, *Stelis labiata* Prov., and *Stelis lateralis* Cresson (Table I). The record of *Melittobia chalybii* Ashmead was probably caused by contamination within the incubator during rearing. Hicks (1926) reported that *H. producta* was parasitized by *L. affinis*. Medler (1958) showed that this parasite is common on bees in trap nests in Wisconsin. *Stelis* parasites are recognized easily in nests because their cocoons are opaque and each bears a tiny nipple at the apex, whereas the cocoon of the host is transparent, parchment-like and has no nipple. The record of *S. labiata* appears to be new, but parasitism by *S. lateralis* is well known, having been reported by Graenicher (1905), Comstock (1924), and Rau (1928). Also, the Colorado record of *Stelis sexmaculata* by Hicks (1926) may refer to *lateralis*. Graenicher (1905) gave an account of the biology of *S. lateralis* (as *sexmaculata*), and recorded 62 per cent parasitism in the Milwaukee area. The data from northern Wisconsin show not more than 15 per cent parasitism by *Stelis* spp. In Colorado, Hicks (1926) found 43 per cent parasitism by *Stelis* spp.

In the vicinity of Milwaukee, Graenicher (1905) found *H. producta* flying from the beginning of June to about the middle of August, and using dry stems of elder, blackberry, sumac and other plants for nesting. In northern Wisconsin, males and females have been collected from the middle of June to late August on flowers of the following plants: white clover, *Trifolium repens* L., alfalfa,

Medicago sativa L., alsike clover, *Trifolium hybridum* L., red clover, *Trifolium repens* L., hawkweed, *Hieracium aurantiacum* L. fireweed, *Epilobium angustifolium* L., goldenrod, *Solidago* spp., black-eyed susan, *Rudbeckia serotina* Nutt., sorrel, *Oxalis europaea* Jord., pearly everlasting, *Anaphalis margaritacea* (L.) Clarke. The bees are especially common on white clover. The nests are provisioned with pollen mostly during June and July, and contain full grown larvae when examined in late July, August or September. These overwinter in diapause and emerge as adults the following spring to complete their one generation life cycle.

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The External Morphology of Two Eastern Species of the Genus *Anoplonyx* (Hymenoptera: Tenthredinidae), with Special Reference to *Anoplonyx luteipes* (Cresson)[1]

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Introduction

The genus *Anoplonyx* Marlatt belongs to the more generalized of the Nematinae and is clearly defined taxonomically by Ross (1937). This genus is comprised of very few known species, four in North America and four in Europe; all are associated with trees of the genus *Larix*. The species are similar in appearance and difficult to distinguish, especially in the adult stage.

Considerable confusion existed concerning the identification of the members of this genus in North America up until Wong (1955) published a key to separate the late feeding stages of *Anoplonyx* larvae found in Canada. The two species dealt with herein are apparently native to Eastern Canada and have generally been identified as one species, "Marlatt's Larch Sawfly", *A. laricis* (Marlatt). Here they are identified as *A. luteipes* (Cresson) (= *laricis* Marlatt), and *A. canadensis* Harrington, as listed by Ross (1951).

The complete external morphology had not previously been worked out for any of the Nearctic species of this genus. This study was undertaken with the purpose of presenting a relatively complete external morphological study of the adult, and to some extent the larvae of *A. luteipes*, with particular reference to difference as they exist with *A. canadensis*. The morphology of the eggs is also discussed briefly; however, the cocoons have been dealt with previously (Wong, 1951) and will not be described here.

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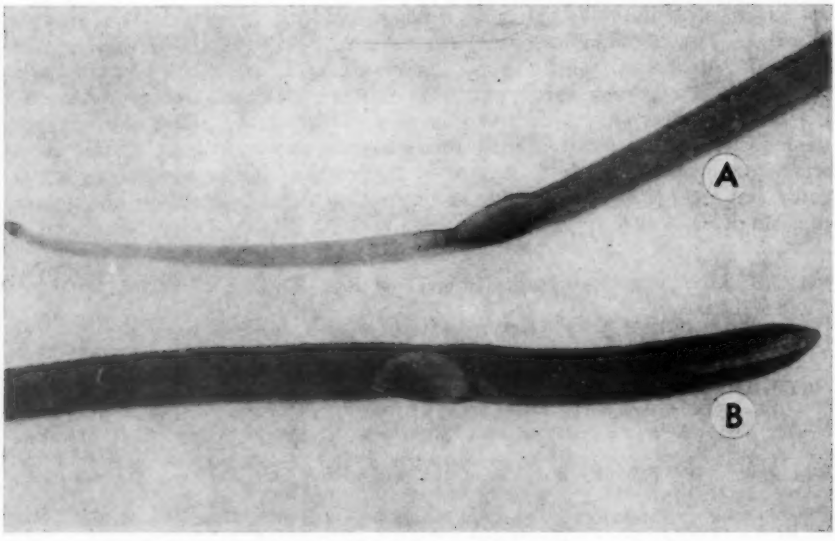


Fig. 1. A. Egg of *A. luteipes;* B. Egg of *A. canadensis.*

Morphology of the Egg

The eggs (Fig. 1) of the two species are similar in size, shape, and colour. They measure approximately 0.94 mm. in length and 0.30 mm. in breadth, being elongate and more or less rounded at both ends, and of a uniform whitish yellow colouration. The surface is smooth and shiny in appearance. At the end of the embryonic development, the egg appears to be a dark brown colour because of the young larva which can be seen clearly through the transparent chorion.

The eggs are deposited in slits cut by the female in the needles, usually one egg per needle, but up to three eggs per needle have been found. The ovipositing slit is usually slightly longer than the length of the egg. The larvae hatch through a cleft on the upper part of the egg, and the chorion remains in the slit in the needle for an undetermined period.

Morphology of the Larva

Wong (1955) published a general taxonomic description of the mature larval characteristics of the genus. The present study is mainly involved with the morphological aspects of the head, along with a brief discussion of the different larval instars and their major distinguishing characteristics.

1st. instar:

The mean head capsule width for the two species is 0.33 ± 0.01 mm., while larval length for preserved specimens of the two species ranges from 1.3 to 3.4 mm. The larvae are pale green in colour with the head of *A. luteipes* a light yellow-brown, and that of *A. canadensis* a dark reddish-brown.

2nd. instar:

Here again the mean head width for the two species is the same, 0.48 ± 0.01 mm., and overall length of the larvae, based on the measurement of preserved material, ranges from 2.8 to 5.2 mm. The larval colour is the same as described for the first instar.

3rd instar:

As in the first and second instars the mean head width of the two species is the same, 0.66 ± 0.02 mm. The overall larval length ranges from 4.5 to 8.0 mm. for preserved material. The head of *A. luteipes* is brown while that of *A. canadensis* is dark brown. The larvae are green in colour and the olive supraspiracular stripe is usually evident (Figs. 2, 3) although the olive addorsal and epipleural stripe (Fig. 2) characteristics of the last instar of *A. luteipes* are not always recognizable.

4th instar:

The mean head width for larvae of *A. luteipes* is 0.99 ± 0.03 mm. At this stage there is a significant difference (significant at the 0.1 per cent level) in the mean head width of male and female larvae of *A. canadensis*. The mean head width for the male is 0.81 ± 0.02 mm., and that of the female 0.89 ± 0.05 mm. The larval colour is as described for the third instar except that the olive addorsal and epipleural stripes, characteristic of *A. luteipes*, are more frequently seen than in the third instar. Here the head of the two species is brown with a darker brown patch on the lower side of the head in *A. canadensis*. The length of the preserved larva ranges from 6.5 to 11.0 mm. for *A. canadensis* and from 7.0 to 12.0 mm. for *A. luteipes*.

5th instar:

The mean head width for *A. luteipes* is 1.18 ± 0.05 mm., while for *A. canadensis* there is a significant difference (significant at the 1.0 per cent level) in the head width of male and female material. The mean head width of the male is 1.01 ± 0.03 mm.,that of the female 1.13 ± 0.06 mm. The larval length of *A. luteipes* ranges from 9.0 to 15.0 mm. and that of *A. canadensis* from 8.5 to 14.0 mm.

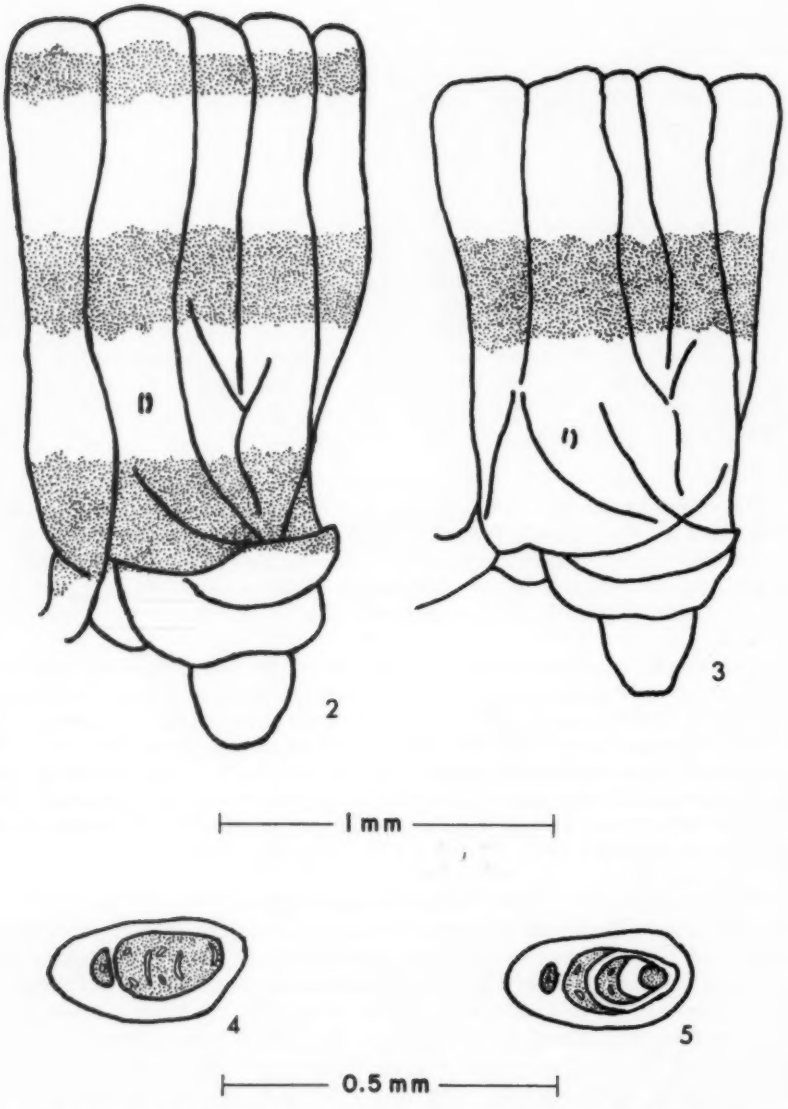
The larvae are tapered caudad with the thorax larger than the abdomen, producing a humped appearance. Larvae are green in colour, with well defined olive green addorsal, supraspiracular, and epipleural stripes in *A. luteipes* (Fig. 2), but only olive green supraspiracular stripes in *A. canadensis* (Fig. 3). The antennae are four-segmented; segment one is small with a light coloured spot, segments two and three may or may not be complete ring-like structures with two light coloured spots, and segment four is mammillate. In *A. canadensis* the segments are compact (Fig. 4), but not in *A. luteipes* (Fig. 5).

The Head and Appendages

The head is almost hemispherical in shape, the cephalic outline subcircular with a slight dorsoventral elongation, the profile flattened posteriorly and rounded anteriorly, tapering ventrad (Figs. 6, 7). Orientation is hypognathous to slightly opisthognathous. The sclerotized cranium, comprising the major portion of the head exoskeleton, is shaped as described for the head in general except for being truncate and open ventrally with the mouthparts articulated around the margin and closing the ventral opening (Fig. 9). Anteriorly the clypeus forms a short, visor-like projection.

For descriptive purposes the cranium may be divided into two general regions, the fronto-parietal and the occipital regions. The occipital region comprises the posterior surface of the cranium while the extensive lateral, dorsal and anterior areas form the frontoparietal region.

The fronto-parietal region is divided into three main areas. Dorsally a narrow line suture, the coronal suture (Fig. 6, CS), extends anteriorly and ven-



Figs. 2-5. Mature Larvae. 2. *A. luteipes*. Lateral aspect of third abdominal segment. 3. *A. canadensis*. Lateral aspect of third abdominal segment. 4. *A. canadensis*. Dorsal aspect of antenna. 5. *A. luteipes*. Dorsal aspect of antenna.

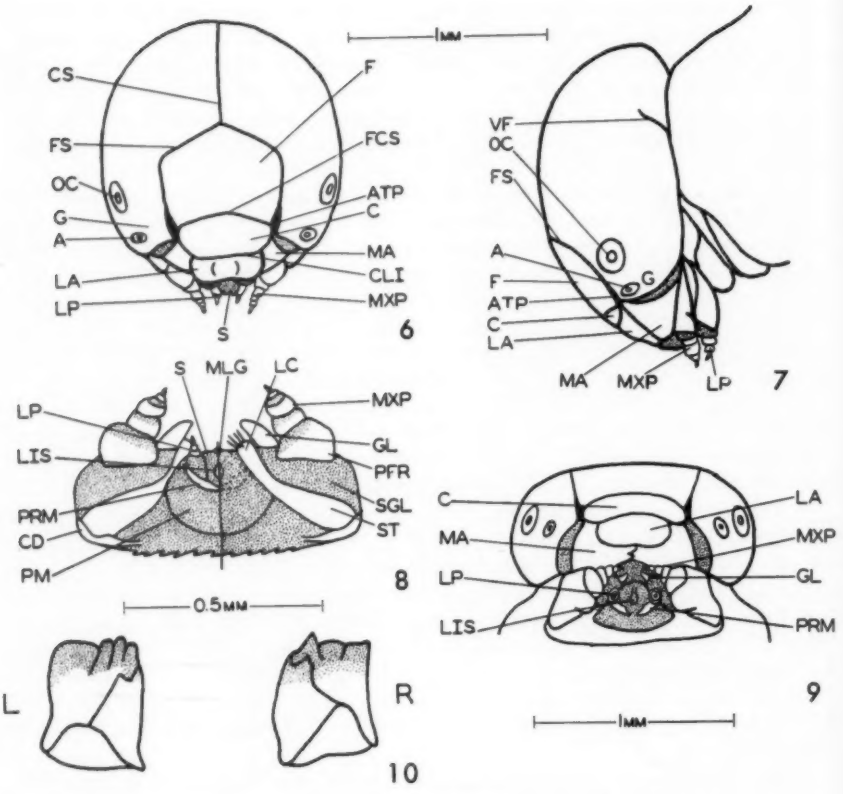
trally to a point approximately one third of the distance to the ventral margin. Here it bifurcates, forming the frontal suture (Fig. 6, FS) which runs ventro-laterally on either side of the mid-cranial line to about the mid-level of the facial area, where it assumes an almost vertical orientation and extends ventrally and slightly mesad ending near the anterior articulation of the mandibles. Along this suture, a small fossa and a thickening of the cuticle indicate the site of the anterior tentorial pits (Figs. 6, 7, ATP). The coronal and frontal sutures are part of an ecdysial line which extends posteriorly through the occipital region and part way along the mid-dorsal line of the thorax. This forms a system which divides the fronto-parietal region of the cranium into an anterior fronto area, the frons (Figs. 6, 7, F), and the two lateral and dorsal areas, the parietals. Dorso-laterally, two short, subparallel sulci, the vertical furrows (Fig. 7, VF) extend anteriorly from the posterior margin of the cranium. The general dorsal area of the cranium bearing the vertical furrows is the vertex. The lateral area of each parietal is the gena (Figs. 6, 7, G). Each gena bears a single ocellus (Figs. 6, 7, OC) slightly below the point where the frontal suture assumes a vertical orientation and closer to this suture than to the posterior margin of the gena. Just ventral and slightly posterior to the ocellus at the level of the anterior tentorial pits, each gena bears an antenna (Figs. 6, 7, A).

The frons may be defined as the facial area bounded ventrally by the dorsally arched frontoclypeal sulcus (Fig. 6, FCS), joining the anterior tentorial invaginations, and laterally and dorsally by the frontal suture. The clypeus (Figs. 6, 7, C) is bound dorsally by the frontoclypeal sulcus, but its lateral borders are free, slanting and convergent ventrad forming a free lobe. The labrum (Figs. 6, 7, LA) is a well sclerotized, small, bilobed flap, articulated to the clypeus by an infolded membrane, the clypeolabral inflection (Fig. 6, CLI). This transverse sclerite is shallowly emarginate in the middle part of its ventral border. The externally visible portion of each ocellus is a clear, lens-like, cuticular thickening.

The mouthparts are well developed and directed ventrad. The mandibles (Fig. 10, MA) are more heavily sclerotized than the other mouthparts and in general are shaped like chisels. Their apical margins are dentate, with dentes on the left mandible more pronounced. When closed the mandibles overlap, the left being the outermost.

The maxillae and the labium (Figs. 8, 9) together form the posterior closing of the intergnathal cavity and of the cranial cavity below the tentorial bridge. Anteriorly only the lateral and ventral margins of the complex are free. Posteriorly the maxillae and labium are largely enclosed in a deep membranous pocket of the prothorax.

Each maxilla (Fig. 8) consists of a basal sclerite, the cardo; a large sclerite, the stipes; two unsegmented processes, the galea and the lacinia; and a segmented palpus. The cardo (Fig. 8, CD) is more or less sclerotized and posteriorly it is narrowly articulated with the postgenal margin and anteriorly there is a broad articulation with the stipes. The stipes (Fig. 8, ST) is elongate and convex with the major portion of it sclerotized. It is continuous laterally with the subgalea (Fig. 8, SGL) to which it is fused along an oblique ridge. In front of the subgalea, a partially membranous swelling forms the palpifer. The palpifer (Fig. 8, PFR) supports a short maxillary palpus (Figs. 8, 9, MXP) of four conical segments. At the tip of the subgalea, a strongly sclerified finger-like process curves toward the labium; this is the galea (Figs. 8, 9, GL). The lacinia (Fig. 8, LC) is a rounded lobe more or less membranous at the tip of the stipes and



Figs. 6-10. Mature Larvae. 6. *A. luteipes*. Cephalic aspect of head. 7. Lateral aspect of head. A, antenna; ATP, anterior tentorial pit; C, clypeus; CLI, clypeolabral inflection; CS, coronal suture; F, frons; FCS, frontoclypeal sulcus; G, gena; LA, labrum; LP, labial palpus; MA, mandible; MXP, maxillary palpus; OC, ocellus; S, spinneret; VF, vertical furrow. 8. Caudal aspect of labiomaxillary complex, with right labial palpus removed showing the lacinia. 9. Ventral aspect of head. 10. Mesal aspect of mandibles. C, clypeus; CD, cardo; GL, galea; LA, labrum; LC, lacinia; LIS, lingular sclerite; LP, labial palpus; MA, mandible; MLG, meatus of labial glands; MXP, maxillary palpus; PFR, palpifer; PM, postmentum; PMR, premental sclerite; S, spinneret; SGL, subgalea; ST, stipes.

contiguous to the galea. It carries a row of four stout bristles on its anterior border.

The labium consists of two flattened lobes situated between and slightly posterior to the maxillae, overlapping them a little. The proximal lobe, the postmentum (Fig. 8, PM), is almost wholly membranous and is joined to the maxillae along its infolded lateral margins. Proximally it is continuous with the cervical membrane. The distal lobe of the labium consists of a U-shaped premental sclerite (Figs. 8, 9, PRM). Distal to each lateral arm of the premental sclerite, and separated from it by a membranous area which is narrow laterally and broad mesad, is a short, three segmented labial palpus (Figs. 8, 9, LP). Between the palpi and slightly anterior to them is the membranous spinneret lobe (Fig. 8, S) with its centrally located meatus of the labial gland (Fig. 8, MLG).

In the midline at the base of the spinneret, between the arms of the premental sclerite, is a triangular lingular sclerite (Figs. 8, 9, LIS).

Morphology of the Female Adult

A. luteipes: Length, approximately 5.0 mm.; robust; shining. Colour black; mouthparts scarcely paler than the general body colour, or very slightly reddish; tegulae and legs pallid, strongly infuscated; coxae black; wings slightly infuscated; veins brown, stigma pale centrally; antennae black.

A. canadensis: Length, approximately 5.0 mm.; rather slender. Colour black; labrum, mandibles, tegulae and legs, except coxae, usually pale honey-yellow; veins of wings pale, especially the costa and stigma; antennae dark brown to black.

The Head and Appendages

The head of *A. luteipes* (Cresson) and *A. canadensis* Harrington is hypognathous. It is of the open head type with the occipital foramen continuous with the oral cavity. It is roughly circular in outline, broader than long, and covered with very short setae. The head is divided into definite areas by sutures or sulci. The sulci mark the position of internal ridges or inflections. From the cephalic aspect the head is convex, with a distinctly defined frontoparietal region (Fig. 11, FP) in *A. luteipes*. With *A. canadensis* the frontoparietal region is distinct, but not so strongly marked. According to DuPorte (1957), the frontoparietal region is a single sclerotized plate, which is partially divided ventrally by the frontogenal sulcus (Fig. 11, FGS) defining a median lobe, the frons (Fig. 11, F) and the two lateral lobes are the genae (Fig. 11, GE). The undivided dorsal area is the vertex (Fig. 11, VE). DuPorte's concept of the frontoparietal region ignores the cleavage lines because they are pale and without internal ridges.

The frontogenal sulcus is very short, extending from the frontoclypeal sulcus (Fig. 11, FCS) to the antennal suture (Fig. 11, AS). The reduction of the area between the frontoclypeal sulcus and the antennal suture results in a short frontogenal sulcus and the small frons. The junction of the frontoclypeal sulcus and the fronto-genal sulcus is marked by a deep invagination, the anterior tentorial pit (Fig. 11, ATP). Extending from the anterior tentorial pit to the anterior mandibular articulation (Fig. 11, AMA) is a groove called by Bigelow (1954) the clypeogenal bridge (Fig. 11, CGB). This bridge marks the division between the clypeus (Fig. 11, CL) and the gena. The clypeogenal bridge according to Bigelow (1954) "serves to cement and support the edges of the clypeus and genae when the latter descend below the original position of the mandibular articulation".

The relatively large, oval antennal sockets (Fig. 11, ANTS) are situated in the centre of the frontoparietal region. On the ventromesal margin of the antennal socket is an elongate antennifer (Fig. 11, AN), which articulates with the antennae. The compound eye (Fig. 11, CE), occupies most of the lateral margin of the head.

A slightly raised rectangular area on the dorsal part of the head is referred to as the postocellar area (Fig. 11, POA) by some taxonomists, and the vertex by others. This is marked laterally by the lateral sulcus (Fig. 11, LS) or temporal suture, and ventrally by a shallow groove, the transverse suture (Fig. 11, TS), which joins the ventral ends of the lateral sulci. The lateral sulcus extends from the lateral ocellus (Fig. 11, LO) to near the caudal margin of the head. The rudimentary coronal suture (Fig. 11, CS) extends dorsally from the transverse suture into the postocellar area. The frontal suture (Fig. 11, FS) extends ven-

trally from the coronal suture for a very short distance on either side of the median ocellus (Fig. 11, MO), but not beyond it.

Below the frons is the narrow clypeus, which lies between the genae and extends to the anterior articulation of the mandibles. It is separated from the frons by the frontoclypeal sulcus (Fig. 11, FCS); from the gena by the clypeogenal bridge; and from the labrum (Fig. 11, LA) by the clypeolabral suture (Fig. 11, CLS). The clypeus is about five times broader than long with the distal margin emarginate. This emargination is usually not so apparent in *A. canadensis*. The labrum, which overhangs the oral cavity, is only about half as broad as the clypeus. It is a setiferous almost rectangular structure about twice as broad as long with the distal margin only slightly emarginate.

The head is concave caudally with an elongate occipital foramen (Fig. 12, OCF). The tentorial bridge (Fig. 12, TB) extends across the occipital foramen. As indicated by Ross (1937) for all adult sawflies, the occipital and occipitopostgenal sutures are absent, making it difficult to differentiate the genae and postgenae. The occipital foramen is surrounded dorsally and laterally by the postoccipital sulcus (Fig. 12, POS). This sulcus cuts off a narrow horseshoe-shaped postocciput (Fig. 12, PO), and defines the occiput (Fig. 12, OC), dorsally and the postgena (Fig. 12, PG) laterally. Two diverging sulci called tentorial thickenings (Fig. 12, TT) outline the lateral boundaries of the occiput. The posterior tentorial pit (Fig. 12, PTP) is relatively large and situated at the lower end of the postoccipital sulcus. The hypostoma (Fig. 12, HST) is well defined on the ventral edge of the postgena by an oblique hypostomal suture (Fig. 12, HS) which extends toward the posterior tentorial pit. The posterior articulation of the mandible (Fig. 12, PAM) is at the ventral end of the hypostoma.

The appendages of the head include a pair of antennae, a pair of mandibles, a pair of maxillae, and the labium. The maxillae and labium are united along the post-mentum (Fig. 12, PM) of the latter and the mesal margin of the cardo and stipes of the former (Fig. 12, CD, ST) to form a composite structure.

The antennae are filiform and covered with very fine setae. Each antenna consists of a rectangular scape (Fig. 13, SC) which has a definite suture in a

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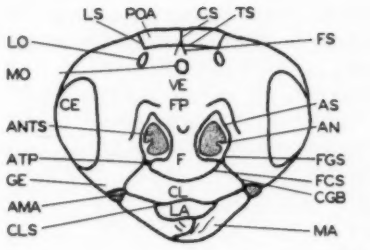
Figs. 11-17. Adult. *A. luteipes*. 11. Cephalic aspect of head. 12. Caudal aspect of head. 13. Lateral aspect of antennae. 14. Cephalic aspect of left mandible. AGL, alaglossa; AMA, anterior mandibular articulation; AN, antennifer; ANTS, antennal socket; AS, antennal suture; ATP, anterior tentorial pit; BL, bulbus; CD, cardo; CE, compound eye; CGB, clypeogenal bridge; CL, clypeus; CLS, clypeolabral suture; CS, coronal suture; F, frons; FCS, frontoclypeal sulcus; FGS, frontogenal sulcus; FL, flagellum; FP, frontoparietal region; FS, frontal suture; GE, gena; GL, galea; HS, hypostomal suture; HST, hypostoma; LA, labrum; LC, lacinia; LO, lateral ocellus; LP, labial palpus; LS, lateral sulcus; MA, mandible; MO, median ocellus; MX, maxillaria; MXP, maxillary palpus; OC, occiput; OCF, occipital foramen; PAM, posterior articulation of mandible; PD, pedicel; PFR, palpifer; PG, postgena; PGL, paraglossa; PGR, palpiger; PM, postmentum; PMS, postmental sclerite; PO, postocciput; POA, postocellar area; POS, postoccipital sulcus; PRM, prementum; PTP, posterior tentorial pit; SC, scape; ST, stipes; TB, tentorial bridge; TS, transverse suture; TT, tentorial thickening; VE, vertex. 15. Ventral aspect of thorax. 16. Dorsal aspect of thorax. 17. Lateral aspect of thorax. AEM, anepimeron; AES, anepisternum; ANP, anterior notal wing process; AOS, anterior oblique sulcus; ASP, anterio-lateral mesoscutal process; BS, basisternum; CN, cenchrus; CSC, cervical sclerite; CX, coxa; DCM, discrimen; DP, discrimenal pit; ENS, external notal sulcus; EPC, epicnemium; EPM, epimeron; EPS, episternum; ES, epimeral sulcus; FRS, furcasternum; I, scutal fissure; KEM, katepimeron; KES, katepisternum; MS, median sulcus; NO, notaulix; PAR, parapsis; PC, pleural cleft; PES, presternum; PF, parapsidal furrow; PH, phragma; PN, pronotal lobe; PNP, posterior notal wing process; PRN, pronotum; PRS, prescutum; PTG, posttergite; PTN, postnotum; SCL, scutellum; SCUT, scutum; SP, spiracle; SS, spinisternum; T, abdominal tergite; TG, tegula; TRO, trochantin; WP, pleural wing process.



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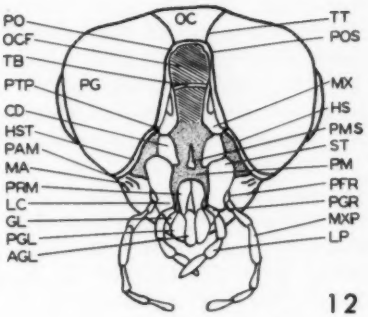

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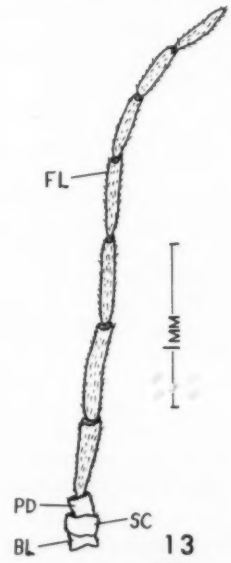

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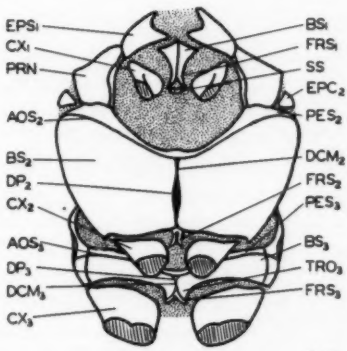

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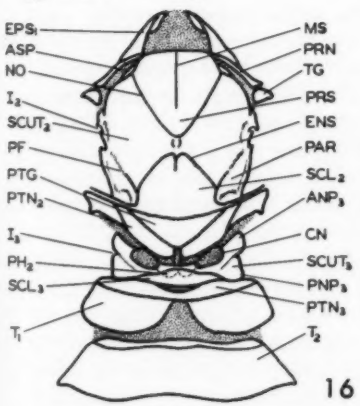

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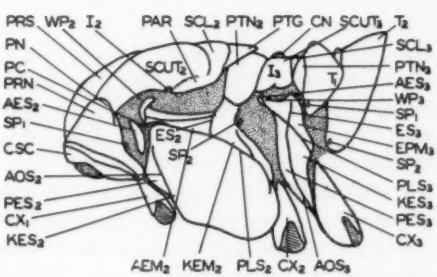

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slight constriction on the basal part, which cuts off the bulbus (Fig. 13, BL); the quadrate pedicel (Fig. 13, PD) is about as long as the scape, and not quite as wide; the flagellum (Fig. 13, FL) contains seven elongate segments. In *A. luteipes* the fourth joint is slightly longer than the third (Fig. 13), but in *A. canadensis* the joints three to five are subequal.

The mandibles (Fig. 14) are dicodylic, heavily sclerotized structures, that taper apically to a point. They possess two dentes, a long, slender lateral one and a shorter, more stout mesal tooth. The left and right mandibles are identical.

The maxilla consists of a more or less triangular cardo (Fig. 12, CD) and elongate stipes (Fig. 12, ST). The cardo is rounded dorsally at which point it articulates with the maxillaria (Fig. 12, MX), and is directed mesally towards the tapered postmental sclerite (Fig. 12, PMS). Distad of the cardo is the stipes, which bears laterally the six-segmented setiferous maxillary palpus (Fig. 12, MXP), the basal segment being the palpifer (Fig. 12, PFR). The stipes bears terminally the galea (Fig. 12, GL), and mesally the lacinia (Fig. 12, LC).

The labium consists of a membranous proximal postmentum (Fig. 12, PM), and a sclerotized distal prementum (Fig. 12, PRM). The postmentum bears an elongate tapered sclerite, the postmental sclerite (Fig. 12, PMS), which is situated mesally between the cardines. This sclerite corresponds with the submentum of Ross (1937). The prementum is roughly M-shaped and bisected by a vertical sulcus and bears three terminal lobes on its distal end. The narrow, elongate medium lobe represents the fused glossae or alaglossa (Fig. 12, AGL), and the larger deltoid lobes on either side are the paraglossae (Fig. 12, PGL). Laterally the prementum carries the four-segmented setiferous labial palpus (Fig. 12, LP), the basal segment being the palpiger (Fig. 12, PGR).

The Thorax and Appendages

The thorax consists of three well defined segments, the pro-, meso- and metathorax. The wing-bearing segments are referred to as the pterothorax. Joining the head to the prothorax is a membrane called the cervix or cervical membrane.

The tergum or notum of the prothorax, referred to as the pronotum (Figs. 16, 17, PRN), is separated from the pleurosternal parts of the prothorax. It is a collar-like plate, very closely associated with the mesothorax. The top of the collar is narrowed, with the sides expanded into a broad triangular plate above the cervical sclerite (Fig. 17, CSC). The caudoventral angle of the pronotum extends to the cephaloventral corner of the presternum (Figs. 15, 17, PES_2) and the epicnemium (Fig. 15, EPC_2). The caudodorsal angle of the pronotum is recessed to form a pronotal lobe (Fig. 17, PN) for the reception of the cephalic margin of the tegula (Fig. 16, TG). The pronotum is grooved by a transverse furrow near its anterior margin, which marks an internal ridge.

The elongate sclerite ventral of the pronotum, has been known as the cervical sclerite, but more recently called the propleuron (Richards, 1956), and in this case is a single sclerite with no pleural sulcus. The apical cephalic margin flares into a pointed process which articulates with the back of the head. The basisternum (Fig. 15, BS) is the T-shaped sternal plate, which is divided longitudinally by a central invagination similar to the discrimen of the mesosternum. The basisternum is slightly concave, extending caudally into a narrow invaginated bifid furcasternum (Fig. 15, FRS_1) of the prothorax. The lateral edges of the furcasternum articulate with the coxa of the prothoracic leg, and a small triangular

spinasternum (Fig. 15, SS) is located just caudad of the furcasternum and marks the point of the internal spina.

The setiferous mesothorax is the largest segment of the thorax. The dorsum is convex and consists of the notum, or alinotum, and the postnotum. The alinotum is composed of the prescutum (Fig. 16, PRS) of Ross (1937), the scutum (Fig. 16, $SCUT_2$), and the scutellum (Fig. 16, SCL_2). The prescutum is roughly triangular with sloping sides. The lateral margin is defined by a pair of converging sulci or notaulices (Fig. 16, NO), that meet at the mid line. A median sulcus (Fig. 16, MS) extends beyond the middle of the prescutum and forms the median ridge internally and is most prominent at the cephalic end. Part of the cephalolateral margin of the prescutum and the scutum is extended outward and slightly inflexed to form a narrow lateral process, the anterolateral mesoscutal process (Fig. 16, ASP). Along the sides and just caudad of the prescutum to the scutellum (Fig. 16, SCL_2) is the scutum (Fig. 16, $SCUT_2$). The lateral margin of the scutum is produced outward to form the anterior notal wing process (Fig. 21, ANP_2), and the posterior notal wing process (Fig. 21, PNP_2). The anterior notal wing process is slightly emarginated to produce a lobe-like cephalic part, and a slightly projecting caudal part. Behind the caudal projection of the anterior notal wing process is a slight curved fissure (Figs. 16, 21, I_2) on the edge of the scutum. Snodgrass (1935) refers to this as the posterior intrascutal groove. The posterior notal wing process is not well differentiated. The caudo-lateral area of the scutum, the parapsis (Fig. 16, PAR) or the parascutellar area is well defined. Cephalad this area is indicated by the diagonal parapsidal furrow (Fig. 16, PF). The scutellum is separated from the scutum by an inverted V-shaped external notal sulcus (Fig. 16, ENS) or the scutoscutellar sulcus. The caudal area of the scutellum is separated into a triangular posttergite (Fig. 16, PTG) by a conspicuous posterior marginal fold of the scutellum. The lateral margin of the posttergite is continuous with the axillary cord of the forewing.

Behind the alinotum and partially hidden by the metanotum is the postnotum (Fig. 16, PTN_2). It is a broad sclerotized collarlike sclerite that is united laterally to the epimeron of the mesothorax, and connected to the alinotum by a membrane. Externally, a narrow membrane between the posttergite and the scutum of the metathorax appears to divide the postnotum into two parts. The posterior margin of the postnotum is produced caudally and ventrally beneath the metatergum to form a second phragma (Fig. 16, PH_2) or postphragma.

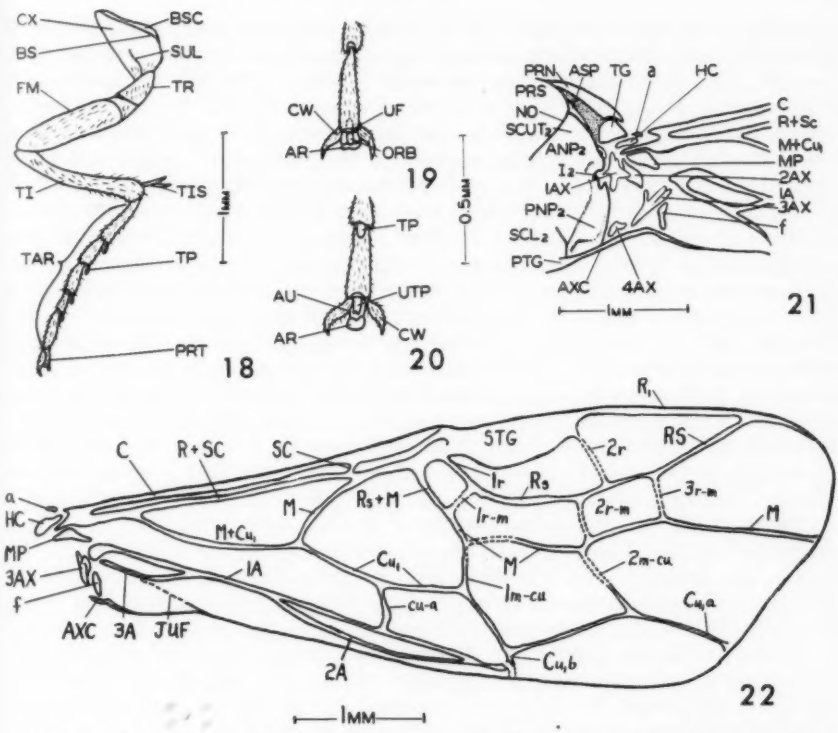
In the dorsal part of the pleuron of the mesothorax is the oblique pleural sulcus (Fig. 17, PLS_2) running dorsad and cephalad from the articulation of the second coxa to the anterior pleural wing process (Fig. 17, WP_2). This sulcus divides the pleuron into the dorsal epimeron and ventral episternum. The epimeron is divided by an epimeral sulcus (Fig. 17, ES_2) into a small, elongate cephalic anepimeron (Fig. 17, AEM_2) and a larger somewhat foot-shaped caudal katepimeron (Fig. 17, KEM_2). The dorsal area of the anepimeron has a transverse sulcus cutting off a very narrow dorsal part and a roughly triangular ventral portion. The episternum is also differentiated into two parts. A small triangular dorsal cephalic piece called the anepisternum (Fig. 17, AES_2) by Richards (1956), and the large prominent rectangular area caudad of the anepisternum is the katepisternum (Fig. 17, KES_2). Just cephalad of the anepisternum is the mesothoracic spiracle (Fig. 17, SP_1). The dorsocephalic corner of the katepisternum is marked by a pleural cleft (Fig. 17, PC). The cephaloventral corner

of the katepisternum is marked by the anterior oblique sulcus (Fig. 17, AOS_2), which extends ventrad to meet the median longitudinal discrimen (Fig. 15, DCM_2). This sulcus cuts off an elongate triangular presternum (Figs. 15, 17, PES_2) or prepectus. Just cephalad of the presternum is a very narrow sclerite, the epicnemium (Fig. 15, EPC_2), which cannot be seen from the lateral aspect.

The episternum extends ventrally to the discrimen (Fig. 15, DCM_2) making it difficult to distinguish the basisternum (Fig. 15, BS_2) from the episternum of the mesothorax. The discrimen is a central, longitudinal line on the basisternum. Along the discrimen is a long narrow discrimenal pit (Fig. 15, DP_2), which occupies the median area of the basisternum. It has been suggested that the episternum has actually extended to the discrimen, and the true sternum has infolded to form the endosternum. Snodgrass (1956) does not agree with this interpretation, and believes, "there is no reason why the cuticular sclerotization may not become confluent where continuity gives some mechanical advantage". Behind the basisternum is the small furcasternum (Fig. 15, FRS_2) which projects caudad as a pair of processes and bends slightly laterad to articulate with the mesoproximal margin of the coxa. The spinasternum is not evident in the mesosternum.

The metathorax is considerably smaller and bears fewer setae than the mesothorax. Also, the metathorax does not possess a prescutum. The scutum (Fig. 16, $SCUT_3$) is narrowed medially and enlarged laterally to produce the anterior and posterior notal wing processes (Fig. 16, ANP_3, PNP_3). Behind the anterior notal wing process is a small fissure on the edge of the scutum (Fig. 16, I_3). This scutal fissure or posterior intrascutal groove is not so pronounced as that of the mesothorax. In the narrow cephalic portion of the scutum is a pair of raised opaque areas, the cenchri (Fig. 15, CN). These are ovate and narrowed toward the meson and appear to extend beyond the cephalic margin of the scutum in the dorsal view. The scutum is separated from the scutellum (Fig. 16, SCL_3) by a deep external scutoscutellor sulcus. This sulcus has its extreme ends bent sharply toward the cauda. The scutellum is narrow, with the caudal margin deflected and is continuous laterally with the axillary cord of the hind wing. The postnotum (Fig. 16, PTN_3) is caudad of the scutellum. It is a narrow collar with an emarginate cephalic margin.

The pleural sulcus (Fig. 17, PLS_3), runs dorsad and cephalad from the lateral articulation with the third coxa to the posterior pleural wing process (Fig. 17, WF_3). It divides the metapleuron into the dorsal epimeron and a ventral episternum. The epimeron (Fig. 17, EPM_3) is only weakly divided into an anepimeron and katepimeron by a rudimentary epimeral sulcus (Fig. 17, ES_3) which is only present at the ventral margin as an extension just above the anterior oblique sulcus (Fig. 17, AOS_3). The dorsal margin of the epimeron is deeply emarginate and then slopes toward the caudal margin. The episternum is divided into a large rectangular katepisternum (Fig. 17, KES_3), and a very small anepisternum (Fig. 17, AES_3). The metathoracic spiracle (Fig. 17, SP_2) is located just caudad of the mesothoracic katepimeron. The episternum, as in the mesothorax, extends ventrally to the discrimen (Fig. 15, DCM_3), the central longitudinal line of the metaventrum, thus causing the episternum to be fused with the basisternum (Fig. 15, BS_3). The anterior oblique sulcus (Fig. 17, AOS_3) at the cephalic margin of the katepisternum, extends ventrally from the pleural sulcus to the discrimen cutting off a narrow presternum (Figs. 15, 17, PES_3) which narrows considerably ventrally. The discrimenal pit (Fig. 15, DP_3) at the cephalic end of the discrimen is small and somewhat triangular. The



Figs. 18-22. Adult. *A. luteipes*. 18. Caudal aspect of left metathoracic leg. 19. Dorsal aspect of pretarsus. 20. Ventral aspect of pretarsus. AR, arolium; AU, auxilia; BS, basicosta sulcus; BSC, basicoxite; CW, claw; CX, coxa; FM, femur; ORB, orbicula; PRT, pretarsus; SUL, sulcus; TAR, tarsus; TI, tibia; TIS, tibial spur; TP, tarsal pulvillus; TR, trochanter; UF, unguifer; UTP, unguitractor plate. 21. Dorsal aspect of base of front wing. 22. Dorsal aspect of front wing. a, costal sclerite of mesothoracic wing; A, anal vein; ANP, anterior notal wing process; ASP, anterolateral mesoscutal process; AX, axillary sclerite; AXC, axillary cord; C, costa; Cu, cubitus; cu-a, cubitoanal crossvein; f, sclerotized plate of mesothoracic wing; HC, humeral complex; I, scutal fissure; JUF, jugal furrow; M, media; m-cu, mediocubital crossvein; MP, median plate; NO, notaulix; PNP, posttergite; r, radial crossvein; R, radius; r-m, radio-medial crossvein; Rs, radial sector; Sc, subcosta; SCL, scutellum; SCUT, scutum; STG, stigma; TG, tegula.

furcasternum (Fig. 15, FRS_3) is as described for the mesothorax, however, here the fusion of the rudimentary trochantin (Fig. 15, TRO_3) with the sternum is more evident externally than in the mesothorax.

Each thoracic leg is setiferous and consists of the following parts (Fig. 18): coxa (CX); trochanter (TR), (which appears to be two-segmented); femur (FM); tibia (TI); tarsus (TAR); and pretarsus (PRT). The legs of the pro, meso- and metathorax are similar, but differ slightly in size and shape of some of the parts. In this paper only the metathoracic leg will be described.

The proximal segment of the leg is the coxa. In the prothoracic leg it has two points of articulation, a pleural and a sternal articulation. In the meso- and metathoracic legs the coxae have pleural, sternal, and trochantinal articulations. The coxa is subquadrate and around the proximal end is a thickened marginal ridge, the basicoxite (Fig. 18, BSC) which is cut off by the basicosta

sulcus (Fig. 18, BS). At the distal end of the coxa is a short, slightly curved sulcus (Fig. 18, SUL) which indicates the point of articulation with the trochanter. The trochanter is small, broadened distally and tapering proximally. The femur is closely associated with the trochanter and has the proximal area marked off by a suture. The very close association of this proximal area with the trochanter gives the impression that the trochanter is two-segmented as in some Odonata. The femur is a relatively broad, elongate segment. The tibia is only slightly longer than the femur whereas in the pro- and mesothoracic legs the femur is slightly longer than the tibia. It has a broad distal end with two strong, sharply pointed spurs (Fig. 18, TIS) located on the distal end. The tarsus is slender and elongate, being longer than the tibia in the metathoracic leg. The tarsus consists of five tarsomeres, which are widened distally. The first subsequent or basitarsus is the longest, being slightly longer than the fifth subsegment or distitarsus. The subsegments two, three, and four, which constitute the mediotarsus are shorter than the basi- or distitarsus. The sub-segments two and three of the mediotarsus are subequal, while the subsegment four is the shortest. The tarsal pulvillus (Fig. 18, TP) is an oval pad situated on the mesodistal surface of the basitarsus and mediotarsus. The pretarsus is the terminal segment of the leg, which consists of a pair of claws (Figs. 19, 20, CW) which articulate dorsally to the unguifer (Fig. 19, UF), a small plate at the end of the distitarsus. The claws are simple, slightly curved, and broadened at the base. The orbicula (Fig. 19, ORB) extends from the apical emargination of the unguifer as a dorsal elongate sclerite. Ventrally the unguitractor plate (Fig. 20, UTP) is a rectangular sclerite with a notch in the distal margin, situated distad of the distitarsus. The unguitractor plate serves for attachment of muscles to move the claws. On either side of the unguitractor plate is a small narrow sclerite known as the auxilia (Fig. 20, AU). The large median distal membranous lobe is the arolium (Figs. 19, 20, AR).

The two pairs of membranous wings are slightly infuscated and spinulate. When in flight the hamuli along the anterior margin of the hind wings are hooked onto a fold along the posterior margin of the front wings. Only the front wings will be described here as the venation of the hind wings is normal for this group.

The front wing is elongate widening distally, and strengthened by veins and crossveins. The anterior and posterior margins are relatively straight, with the distal margin tending to curve. Above and cephalad of the base of the wing is a quadrate, sclerotized plate, the tegula (Fig. 21, TG). Caudad of the tegula there is an irregular sclerotization of the wing base called the humeral complex (Figs. 21, 22 HC) by Snodgrass (1956). This is apparently formed from an enlargement of the united bases of the costa (C), radius (R) + sub-costa (Sc) and the media (M) + cubitus (Cu). Four axillary sclerites and a median plate are situated in the basal membranous area of the front wing. The first axillary (Fig. 21, 1AX) is a large sclerite with four processes which articulate with the cephalic and caudal portions of the anterior notal wing process (Fig. 21, ANP_2), the humeral complex dorsally, and the central area of the second axillary (Fig. 21, 2AX). The second axillary is somewhat triangular and articulates with the first axillary, the common base of the veins R + Sc and M + Cu_1, and caudally with the third axillary (Figs. 21, 22, 3AX). The third axillary is an elongate Y-shaped sclerite, having three processes. In addition to its articulation with the second axillary it also articulates with the bases of the anal veins and proximally with the fourth axillary (Fig. 21, 4AX). The fourth axillary is the smallest and

may be a detached piece from the posterior notal wing process (Fig. 21, PNP_2). It is irregular in shape and articulates with the third axillary and proximally with the posterior notal wing process. The median plate (Figs. 21, 22 MP) is irregularly shaped and lies in front of the second axillary and abutting the common base of the veins R + Sc and M + Cu_1, and articulates with the bases of the anal veins. Between the third axillary and the axillary cord (Figs. 21, 22, AXC) is a small elongate sclerotized plate (Figs. 21, 22, f). The axillary cord is a thickened, corrugated ligament at the caudal edge of the wing, and is continuous with the lateral prolongation of the scutellum.

The costa (Fig. 22, C), running along the anterior margin of the front wing, is strongly swollen at the apex. The stigma (Fig. 22, STG) in the case of *A. luteipes* is brown and pale centrally, and entirely pale in *A. canadensis*. This is an elongate area situated near the centre of the costal margin. The costa is united to the common basal vein of R + Sc and M + Cu_1 at the base of the wing. The base of the costa appears to have fragmented into a small proximal sclerite (Figs. 21, 22, a) on the cephalic border of the humeral complex. Caudad of the costa is the common basal vein of the cephalic R + Sc vein and the M + Cu_1 vein. The subcosta (Fig. 22, Sc) extends cephalad after separating from the common vein R + Sc just at the beginning of the thickened end of the costa. The radius extends distad of the subcosta to join the media (Fig. 22, M) forming R + M. The common vein R + M divides into R_1 (radius one) and Rs + M (radial sector + media). The vein R_1 runs proximal and distad of the stigma on the cephalic margin to slightly beyond the distal end of Rs. The common vein Rs + M divides to produce the cephalic vein Rs, which slopes cephalad to meet the vein R_1; and the caudal vein M, which extends to, but does not quite touch, the distal margin of the wing. A short cross-vein (Fig. 22, 1r) is present between R_1 and Rs. In addition a marginal crossvein (Fig. 22, 2r) is almost always present between R_1 and Rs in *A. luteipes*, thus forming two marginal cells, whereas, this marginal crossvein 2r, is usually absent in *A. canadensis*. Between Rs and M are three crossveins (Fig. 22, 1r-m, 2r-m and 3r-m) all of which are atrophied at the centre. Thus we have the formation of four submarginal cells. The median and cubitus veins (M + Cu_1) separate from the common basal vein, and continue almost to the centre of the wing, where the media (Fig. 22, M) splits from the cubitus (Fig. 22, Cu_1). The media runs cephalad to join Rs for a short distance and then separates again to extend to the distal margin. The cubitus continues for a short distance and divides into the distal Cu_1a and caudal Cu_1b. Vein Cu_1a extends almost to the distal margin, and vein Cu_1b runs caudad to join with the combined anal veins. Between M and Cu_1 are two crossveins, 1 m-cu and 2 m-cu, each of which is received by the second submarginal cell (Fig. 22). The cephalic ends of these cross-veins and the proximal one-third of the media enclosed by these cross-veins are atrophied. According to Ross (1936) "in the hymenopterous wing, the anal veins (1A, 2A and 3A) (Fig. 22) arise close together at the base", as is the case here. The largest one is 1A, and it articulates with the sclerite 3AX. The vein 2A and 3A is fused for a relatively long distance in its median area with 1A. The basal portion of this vein (3A) is present thus forming a well defined first anal cell. The distal portion of the vein 2A and 3A (2A) unites with the vein 1A at both ends thus forming a second anal cell. The distal end of the combined anal veins runs into Cu_1b, at which point there is a weakened junction. In addition, there is a strong crossvein cu-a between Cu_1 and 1A. The jugal furrow (Fig. 22, JUF) separates the anal region from the jugal fold.

The Abdomen and Ovipositor

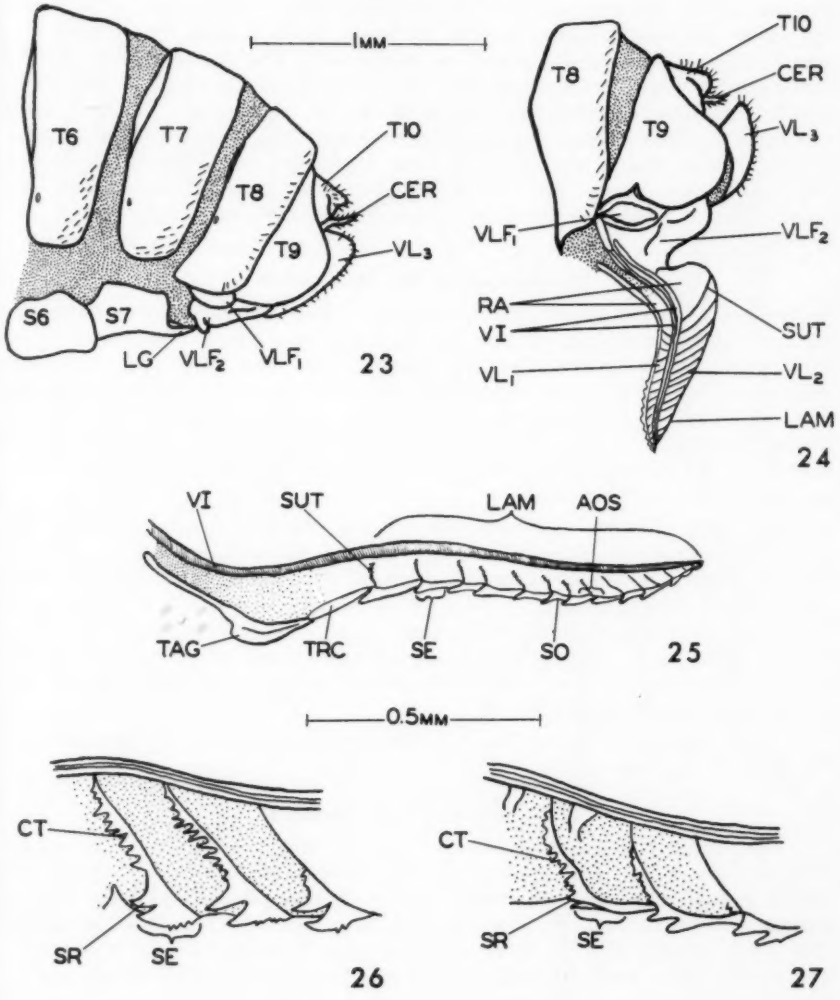
The setiferous abdomen is broadly joined to the thorax. It consists of ten segments, and carries the external genitalia and a pair of short, tapered, setiferous appendages, the cerci (Figs. 23, 24, CER), on the tenth segment. The spiracles which are located on the first eight segments, are quite large.

The tergum of the first abdominal segment is narrow dorsally then broadens laterally into two triangular plates. The sternum of the first segment is membranous. Abdominal segments 2 to 7 are almost identical each having a dorsolateral arch-like tergum (Fig. 23, T), and a transverse line marking off a narrow cephalic part and a wider caudad part. The sternum is plate-like and emarginate mesally on the cephalic margin. The tergum and sternum are separated by a membranous area.

The eighth tergum (Fig. 23, T8) is unmodified. The ninth tergum (Fig. 23, T9), which is narrowed dorsally and overlapped by the eighth tergum, is visible laterally as a large triangular sclerite. The tenth tergum (Fig. 23, T10) is a crescent-shaped terminal piece above the anus. The seventh sternum (Fig. 23, S7) forms the subgenial plate, and is produced mesally at the caudal margin to form the ligamentum (Fig. 23, LG). The eighth and ninth sternites of the female are absent.

The origin of the ovipositor of the female has been regarded as a modification of the leg appendages of the eighth and ninth segments. Indications suggest that the external genitalia of insects are sternal in origin, (Matsuda, 1958). The first valvifer (Figs. 23, 24, VLF_1) is a small, elongate plate ventrad of the ninth tergum and articulating with it. It gives rise cephalad and ventrally to a narrow first valvula (Figs. 24, 25, VL_1) or lancet. A long rod-like groove, the virga (Figs. 24, 25, VI) or ramus, is present on the inner surface near the dorsal margin of the lancet. The virga curves dorsad to the cephalic angle of the first valfiver. The proximal portion of the lancet has a long radix (Fig. 24, RA), which is mostly membranous but slightly sclerotized apically. The radix has on the ventral margin a sclerotized cord the tractium (Fig. 25, TRC), which is enlarged slightly at the heel to form an elongated tangium (Fig. 25, TAG). The distal portion of the lancet is the lamnium (Fig. 25, LAM), which tapers gradually to a blunt point, and curves dorsally at the apex. The lamnium is divided into 13 or 14 segments (sometimes 15 in *A. canadensis*) by sutures (Fig. 25, SUT) or annuli. The ventral margin of each segment usually forms a definite serrula (Fig. 25, SE). In *A. canadensis* the first five or six serrulae have small teeth (Fig. 26), however, the serrulae of *A. luteipes* are smooth (Fig. 27). It is also evident that the serrulae of *A. canadensis* are larger and more pronounced than those of *A. luteipes*. The first eight sutures bear a comb-like row of spines to form a ctenidium (Figs. 26, 27, CT). Near the ventral margin there is a definite spur, the spiculella (Figs. 26, 27, SR). The ctenidium and spiculella of *A. canadensis* (Fig. 26) are more pronounced than in *A. luteipes* (Fig. 27). The sclerotized ventral border of the lamnium is the sclerora (Fig. 25, SO), which is divided into sections called abscissae (Plate 25, AOS).

The second valvifer (Figs. 23, 24, VLF_2) is a large elongated plate with a slight medial concavity. It lies ventrad of the first valvifer and beneath the eighth and ninth terga, and articulates with the caudoventral margin of the first valvifer. The second valvifer gives rise cephalad and ventrally to a narrow pointed second valvula (Fig. 23, VL_2) or lance with a narrow proximal neck. The lance is divided into 14 segments by ridge-like sutures (Fig. 24, SUT), and like the lancet it has a large proximal portion, the radix (Fig. 24, RA), and a



Figs. 23-27. Adult. 23. *A. luteipes*. Lateral aspect of terminal segments of female abdomen. 24. *A. luteipes*. Entolateral aspect of female ovipositor. 25. *A. luteipes*. Lateral aspect of lancet. 26. *A. canadensis*. Lateral aspect of a section of the lancet. 27. *A. luteipes* Lateral aspect of a section of the lancet. AOS, abscissa of sclerora; CER, cercus; CT, stenidium; LAM, lamnium; LG, ligamentum; RA, radix; S, abdominal sternite; SE, serrula; SO, sclerora; SR, spiculella; SUT, suture; T. abdominal tergite; TAG, tangium; TRC, tractium; VI, virgae; VL, valvula; VLF, valvifer.

tapering blade-like distal portion, the lamnium (Fig. 24, LAM). A rod-like groove, the virga (Fig. 24, VI) or ramas is present near the ventral margin of the lateral surface of the lance. The virga of the lance curves dorsad and is attached to the cephalic margin of the second valvifer. The virgae of the lance and lancet are interlocked to permit the lancet to slide back and forth. The dorsal edges of the lance are joined by membrane. The second valvifer articulates caudally with a broad, flattened lobe, the third valvula (Figs. 23, 24, VL_3), which is separated from the former by a narrow membrane. The two third valvulae are joined at their dorsal proximal margin by membrane, thus forming a sheath. The sheath possesses stiff setae especially along the apical margin and smaller ones along the ventral margin. The second valvifers and the sheath form a protective structure which contains the retracted, hinged saw in repose.

Morphology of the Male Adult

A. luteipes: Length, approximately 4.5 mm. Head and thorax practically impunctate; anterior margin of clypeus shallowly emarginate. Antennae black, third joint slightly shorter than the fourth, fourth and fifth joints subequal; wings hyaline, veins brown, costa and stigma dull brown, marginal crossvein present and received beyond the middle of the third submarginal cell which is longer than broad, second submarginal cell receiving both the recurrent crossveins. Colour shining black; coxae, trochanters and base of femora black, tibiae and tarsi dusky.

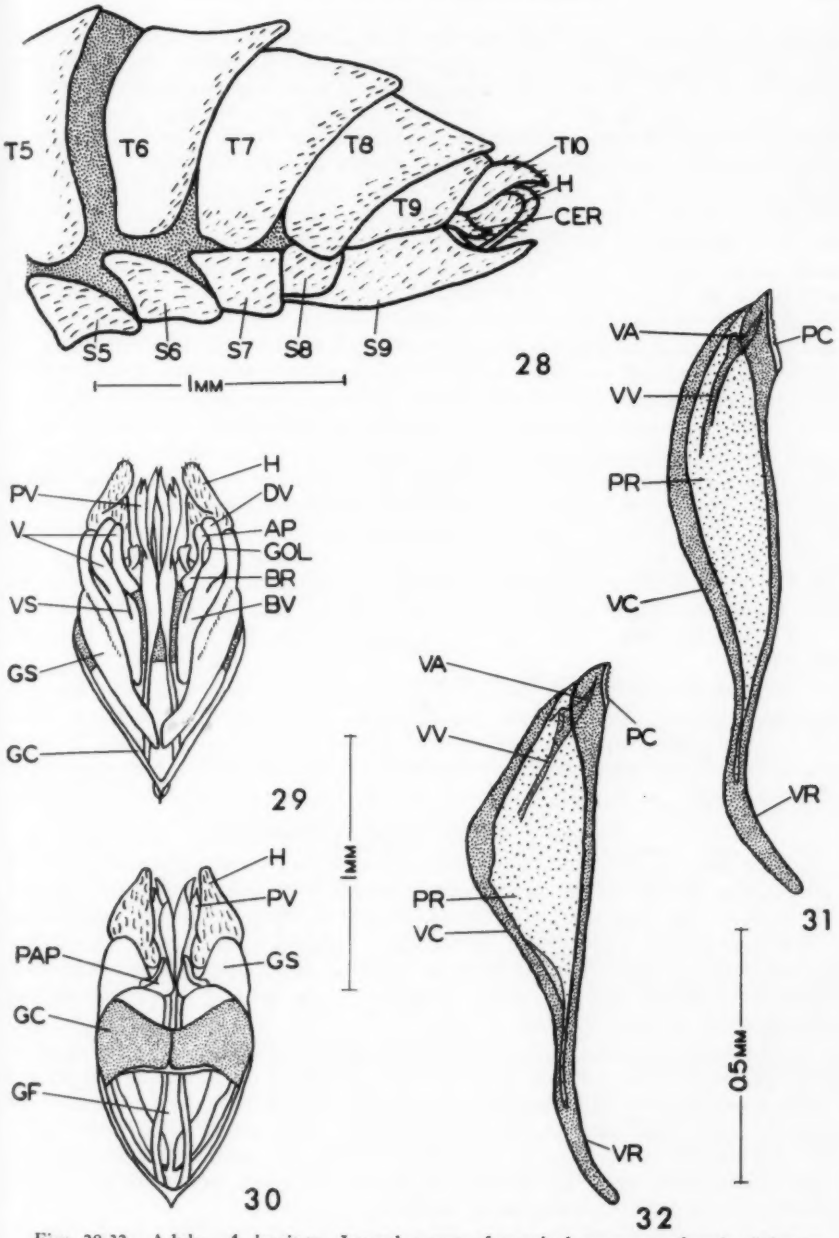
A. canadensis: Length, approximately 4.5 mm. Head and thorax shining and practically impunctate; anterior margin of clypeus shallowly emarginate. Apical joint of antenna somewhat flattened, antennal joints three, four, and five subequal, antennal segments three to nine brownish; wings hyaline, veins pale brownish, marginal crossvein usually absent and when present received before middle of the third submarginal cell, second submarginal cell receiving both the recurrent crossveins. Colour black; labrum and mandibles yellowish brown, legs except coxae usually yellowish.

Morphologically the male resembles the female except for the genitalia and the terminal segments of the abdomen.

The Abdomen and Genitalia

The eighth tergum (Fig. 28, T8) has a convex mesal area at the caudal margin. The ninth tergum (Fig. 28, T9) is reduced and overlapped by the eighth to such an extent as to expose only a narrow plate dorsally and a small triangular piece on each side in front of the short tapered cercus (Fig. 28, CER). The tenth tergum (Fig. 28, T10) resembles that of the female, but is narrower and slightly more arched. Unlike the female, the eighth and ninth sternites are present in the male. The eighth sternum (Fig. 28, S8) is visible only as a small quadrate piece. The ninth sternum (Fig. 28, S9) is a large plate covering the male genitalia, and forms a concave subgenital plate or hypandrium, which is broadly tapered caudally.

The male genitalia are presently believed to be sternal in origin (Matsuda, 1958), and not modified leg appendages of the ninth segment. In the two species considered here they are in the form of a slightly elongated, more or less heart-shaped capsule (Figs. 29, 30). The capsule has at the base, the gonocardo (Figs. 29, 30, GC), a ring-like structure, that narrows cephalad to a genital foramen (Fig. 30, GF). Ventrally the gonocardo is a broad, mesally emarginate band (Fig. 30, GC) that narrows considerably dorsally (Fig. 29, GC). A pair



Figs. 28-32. Adult. *A. luteipes*. Lateral aspect of terminal segments of male abdomen. CER, cercus; H, harpes; S, abdominal sternite; T, abdominal tergite. 29. Dorsal aspect of male genitalia. 30. Ventral aspect of male genitalia. 31. Lateral aspect of penis valve. 32. *A. canadensis*. Lateral aspect of penis valve. AP, apiceps; BR, basiura; BV, basivolsella; DV, distivolsella; GC, gonocardo; GF, genital foramen; GOL, gonolacinia; GS, gonostipes; H, harpes; PAP, parapenis; PC, pseudoceps; PR, paravalva; PV, penis valve; V, volsella; VA, valvispina; VC, valviceps; VR, valvura; VS, volsellar strut; VV, valvar strut.

of lateral clasper-like appendages are distad of the gonocardo. Each appendage is a gonoforceps consisting of a large curved proximal portion, the gonostipes (Figs. 29, 30, GS), and a roughly triangular, setiferous articulating distal portion, the harpes (Figs. 29, 30, H). The mesoproximal area of each gonostipes is produced mesad on the ventral aspect to form triangular structures, the parapenes (Fig. 30, PAP) which are fused along a sharply invaginated mesal margin, and slope to a distal point. On the dorsal surface there are two structures which constitute the volsellae (Fig. 29, V), and are joined laterally to the mesal margin of the gonostipes. The large basal portion of each volsella is known as the basivolsella (Fig. 27, BV). A slightly curved volsellar strut (Fig. 29, VS) is evident in the basivolsella. The volsella has two distal lobes, the distivolsella (Fig. 29, DV), a small lateral lobe which is a continuation of the basivolsella, and a larger mesal lobe, the gonolacinia (Fig. 29, GOL), which is connected to the mesal margin of the basivolsella. The apical portion of the gonolacinia is the apiceps (Fig. 29, AP) and the tail-like portion is the basiura (Fig. 27, BR). The central structure between the volsellae is the aedeagus consisting of a membranous median area, and a pair of elongate lateral penis valves (Figs. 29, 30, PV). The penis valves are hinged by membrane along the ventrodistal surface. Each penis valve has a sclerotized tail-like proximal part, the valvura (Figs. 31, 32, VR), and a body-like distal part, the valviceps (Figs. 31, 32, VC). The valviceps has a sclerotized mesodorsal thickening or valvar strut (Figs. 31, 32, VV). In addition, the valviceps can be subdivided at the apex into a mesal flap, the pseudoceps (Figs. 31, 32, PC) and a lateral flap, the paravalva (Figs. 31, 32, PR), which bears at its apex a sclerotized spine, the valvispina (Figs. 31, 32, VA).

The penis valves of *A. luteipes* (Fig. 31) and *A. canadensis* (Fig. 32) can be seen to differ in their general over-all shape. The body-like valviceps (VC) of *A. luteipes* being narrower and more elongated than that of *A. canadensis*, and the mesal margin being slightly S-shaped in *A. luteipes*, and almost straight in *A. canadensis*.

Summary of Differentiating Characters

The only important characters which permit the separation of mature larvae of the two species is the presence of the addorsal and epipleural stripes in *A. luteipes*, and their absence in *A. canadensis*. Larvae in the first and second instars can usually be separated by the light yellow-brown head of *A. luteipes* as compared to the dark reddish-brown head of *A. canadensis*. No other character observed was sufficiently consistent to be used in separating the immature larvae of these species.

The adult females can always be separated by differences in the lancet of their genitalia. The serrulae on the ventral margin of the lancet are larger and more pronounced in *A. canadensis* than in *A. luteipes*, and the first five or six serrulae have small teeth in the former whereas they are smooth in the latter. In addition, the comb-like row of spines forming the ctenidium, and the large spur or spiculella near the ventral margin of the lancet, are much more pronounced in *A. canadensis* than in *A. luteipes*.

The adult males of the two species are easily separated by relatively consistent differences in the antennae and wing venation. The antennae of *A. luteipes* are black, with the third joint slightly shorter than the fourth, and the fourth and fifth joints subequal. In *A. canadensis*, the antennal segments three to nine are brown, and the segments three, four and five are subequal. The marginal crossvein in the forewing of *A. luteipes* is present and received beyond

the middle of the third submarginal cell, whereas, this marginal crossvein is usually absent in the forewing of *A. canadensis*, or if present, it is received before the middle of the third submarginal cell.

The most satisfactory character for separating the males of these two species is the penis valves which differ in their general overall shape. The body-like valviceps of the penis valve of *A. luteipes* is narrower and more elongated than that of *A. canadensis*, and the mesal margin of the penis valve is slightly S-shaped in the case of *A. luteipes*, and almost straight for *A. canadensis*.

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Second Diapause in Spruce Budworm from Eastern Canada[1]

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In eastern Canada larvae of the spruce budworm, *Choristoneura fumiferana* (Clem.), complete their development in one year, undergoing only one period of winter diapause in the second instar, whereas in certain parts of British Columbia, at high altitudes, two years are normally required for development, the larvae spending a second period of winter diapause in the fourth instar (3, 9). Among laboratory-reared eastern budworm there are a few individuals that enter a similar second diapause (7). The low incidence and somewhat irregular occurrence of this second diapause in eastern budworm, even in laboratory rearings, have hitherto made detailed studies almost impossible, but unusual storage times and treatments used recently in rearing experiments had the unexpected effect of increasing the incidence of this type of behaviour to a level where experimental analysis became possible. This paper describes these larvae and their behaviour; an account of the effects of various conditions upon the incidence of second diapause will be presented later.

Behaviour and Identification

Individual larvae destined to undergo a second diapause cannot at first be distinguished from those that develop normally. Both types feed actively during the second instar, following their first diapause, and during the first few days of the third instar. Part way through the third instar, however, differences appear that can be detected in carefully controlled rearings (13). Insects that will enter second diapause stop feeding at this time, often leaving the buds, particularly if these are fresh. During the next two to four weeks there are gradual changes in their appearance, which soon suffice to identify them as second diapause individuals. These changes are similar to those that precede the second-instar diapause (7), i.e., a gradual decrease in size, by about 30 per cent, accompanied by a deepening of pigmentation to a reddish brown. During this period the larvae also become progressively less active and somewhat less responsive to tactile stimuli.

In the standard technique used in laboratory rearing (13), the first routine examination and food change of developing larvae, known as the 'establishment check', is made 10 to 14 days after the emerged larvae have been placed on freshly-thawed balsam fir buds. By this time most larvae have reached the fourth or fifth instar, but a few are still in the third (Fig. 1). Most of the third-instar larvae appear quite normal and are usually about to moult, but a few may be somewhat smaller, slightly darker, and less active. Although, on the basis of this first examination it is not possible to determine whether these larvae have already stopped feeding, their appearance suggests that they are entering second diapause. They can, therefore, be recorded as "possible second diapause", but are usually returned to their petri dishes with some fresh food.

Some time after cessation of feeding and after the above-noted changes in appearance and behaviour become apparent, most second-diapause larvae construct hibernacula, if left undisturbed. When spun in the buds such hibernacula may at first be difficult to distinguish from the silk of the larval feeding tunnel. When spun elsewhere in the petri dish rearing container, the completed hibernaculum is seen to be formed of a tough dense web, similar to, but larger and more substantial than that built by the first-instar larva (Fig. 2B). After completion of the hiber-

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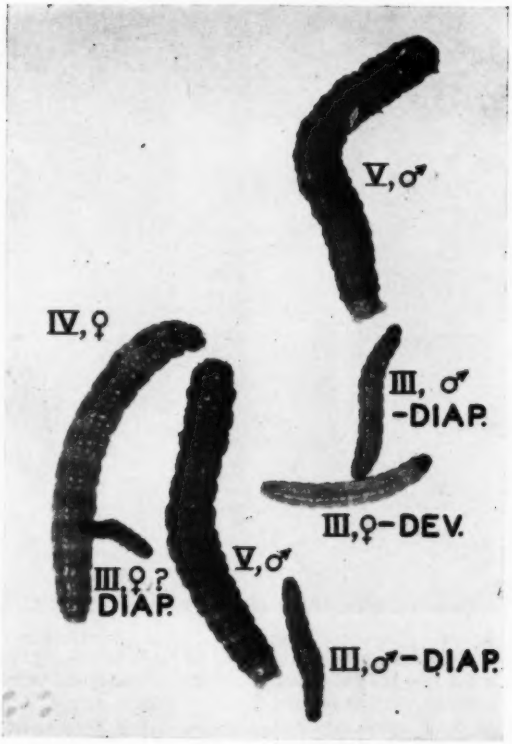

Fig. 1. Larvae present in a rearing dish at the establishment check, 12 days after emergence from their hibernacula. Probable instar and sex of the larvae are shown; probable second-diapause larvae indicated as DIAP. 4x.

naculum most larvae moult; the cast skin and head-capsule are almost invariably found within the hibernaculum (Figs. 2A and B). Fresh food supplied to the larvae after they cease feeding, or to larvae removed from their hibernacula, is usually ignored.

Following the establishment check in routine rearings, subsequent checks of petri dishes are made at about weekly intervals, and all larvae accounted for, if possible. Larvae that, at the establishment check, have been designated as possible second diapause are examined carefully. If they appear and behave as second-diapause larvae, they may be so classified. This was the case of the insects shown in Fig. 1: 5 days after the establishment check most larvae in this dish were in the fifth or sixth instar, while the three "possible second-diapause" larvae had scarcely changed. The developing larvae all pupated between the 25th and 33rd day, and all became adults. On the 38th day only two male larvae remained in the dish; both had constructed hibernacula and moulted, thus, were in their fourth instar and definitely in second diapause. This example illustrates the method used in identifying second-diapause larvae before they spin or moult, without disrupting the normal rearing procedure or segregating diapausing larvae. After removal of the sixth-instar larvae to individual vials (13), usually by the third week, corrugated cardboard rolls may be placed in the petri dish to provide better spinning sites, as many of the second-diapause larvae will not have spun yet.

Fig. 2. *A*. A second-diapause budworm in an opened hibernaculum in a balsam fir bud (note cast head-capsule). 14x. *B*. Second-diapause larvae in hibernacula spun between corrugated paper and glass, showing head-capsule and cast skin enclosed in a walled-off chamber. 10x.

When second-diapause larvae have completed their hibernacula, they must be placed in cold storage (0-10°C) to permit resumption of development. With the exception of the few larvae that fail to spin adequate hibernacula or to moult, second-diapause larvae have a fair chance of surviving and developing to maturity. Storage survival of second-diapause larvae is not, however, as good as that of first-diapause larvae receiving the same treatment (13).

Instar Determination

One difficulty encountered early in the study of second diapause was the determination of the instar in which diapause occurred. Although it seemed fairly certain that most larvae reached the third instar before moulting into diapause, the diapausing fourth-instar larvae were scarcely larger than thirds. Since in living material there are no other distinctive characteristics available to separate these two instars, instar determination is difficult unless cast head-capsules can be found. To clarify this situation, head-capsule widths of 179 preserved second-diapause larvae and their moulted head-capsules were measured with a Leitz screw micrometer eyepiece; the results are presented as a histogram in Fig. 3. Instar-size limits reported for field-reared budworm (10) are shown in the figure for comparison. The measurement data are also summarized in Table I, along with comparable data for laboratory- and field-reared eastern and field-reared western budworm. The table also shows the percentage distribution of second-diapause larvae according to instar, and percentage size increases at successive instars in second-diapause and developing larvae of the different types.

For 34 of the larvae measured (solid bars in Fig. 3), both second- and third-instar head-capsules were found, thus proving that these insects had diapaused in

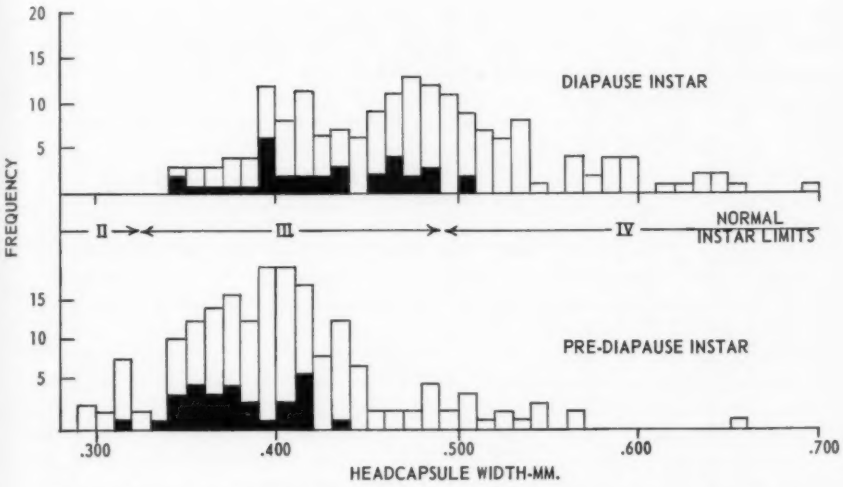

Fig. 3. Frequency distribution of head-capsule widths of prediapause and diapause instars of 179 budworm larvae. Solid bars show measurements of a series of 34 larvae, for which the pre-diapause instar was known to be the third instar. Instar size-limits from field data of McGugan (10).

the fourth instar. In most of the others the head-capsule of only the pre-diapause instar could be found, but this proved sufficient for instar determination in most cases. On the basis of the head-width measurements, the pre-diapause instar of 78 per cent of the larvae was the third and, thus, the diapause instar was the fourth. A few of the pre-diapause larvae (6.7 per cent) were, as shown in Fig. 3, smaller than the lower size limit for the third instar, so have been considered as second-instar larvae, diapausing in the third instar. Other than the size measurement there is no proof, however, that these larvae were not unusually small third-instar larvae, diapausing in the fourth instar. A number of the larvae were larger in their pre-diapause instar than the upper limit of size for the third instar (10), being probably in their fourth instar and, thus, diapausing as fifth-instar larvae. For several of these larvae two moulted head-capsules were found, the smaller of which was still much larger than expected for the second instar, proving them to be in the fifth instar. In all 15.6 per cent of the diapausing larvae studied were apparently in their fifth instar. Nevertheless, although there are some exceptions, second diapause in eastern budworm usually takes place in the fourth instar. Head widths of all diapausing larvae were much below the expected size for their instar (Fig. 3; Table I); many of them were, in fact, still within the size limits of the previous instar, thus providing an explanation for the difficulties encountered in attempting to determine instars visually.

Crochet number has been found to be useful in separating the third and fourth instars in field-reared budworm (10), the average number of crochets, based on counts of four abdominal prolegs of each larva, being 14.2 and 21.4, respectively. Forty-seven larvae diapausing in the fourth instar had an average crochet number of 13.6, which is slightly below that expected for third-instar larvae and, obviously, of no use in instar determination. Moreover, the crochets were mostly uniordinal, as is typical of the third instar (10), although a few showed sufficient variation to suggest a biordinal condition. Regression analysis revealed a highly significant correlation coefficient ($r = 0.87$) between head-capsule widths and

TABLE I.

Mean head-capsule widths and percentage increases in size for successive instars in laboratory-reared budworm compared to those of field-reared budworm from eastern Canada (10) and from two-year cycle areas in British Columbia (12), except for those values marked [2] which are unpublished results of J. A. Cook. Values in parenthesis are interpolated to complete the series. The column headed "Distrib." shows the percentage distribution of the experimental series according to the instar in which they diapaused.

Instar		LABORATORY-REARED EASTERN BUDWORM						FIELD-REARED			
		DEVELOPING		DIAPAUSING				EASTERN		WESTERN	
				Pre-Diap. Second - Diapause							
		Mean Width	Size Incr.	[1]M. Width	M. Width	Incr.	Distrib.	Mean Width	Size Incr.	Mean Width	Size Incr.
		mm	%	mm	mm	%	%	mm	%	mm	%
I		.254	—	—	—	—	—	.252	—	.263	—
II		.309	22	.309	—	—	—	.314	25	.317[2]	20
III		(.445)	(44)	.396	.379	23	6.7	.445	42	.537[2]	69
IV		.682	(53)	.512	.468	18	77.7	.682	53	.626	16
V	♀	1.11	62	—	.579	13	15.6	1.15	69	1.108	77
	♂	1.06	56					1.06	56	1.103	65
VI	♀	1.68	51	—	—	—		1.79	56	1.920	73
	♂	1.50	41					1.63	54	1.817	76

[1]Size increase values show as a percentage the ratio of the difference in size between successive instars to the size of the smaller, preceding instar.

crochet numbers of diapausing larvae. These measures are, then, simply two different expressions of general size and do not indicate different instars. Since neither measurement is adequate for instar determination of second-diapause larvae, the number of moults or the head size of the pre-diapause instar must be used where this information is needed.

Discussion

The recognition and handling of second-diapause larvae in routine rearings have caused some difficulties in the past. Before it was realized that this behaviour could occur in eastern budworm, such individuals were usually transferred to fresh food repeatedly until they died. Because of their small size many were undoubtedly not found during rearing checks. With the recognition of the existence of this type of behaviour, adjustments in the standard rearing technique have been made to take it into account. Confirmation of the early tentative identification of second-diapause larvae at a subsequent check permits precautions to improve their chances of survival during storage, if they represent valuable stocks. If there is no need to continue their rearing and as their numbers are not large they can be discarded.

Second-diapause individuals have been found in most rearings of eastern budworm under the controlled conditions of our rearing room (21°C; 70% R.H.; 16-hour photoperiod), both in laboratory stocks and among the progenies of collections from many different populations. The incidence is generally low, however, averaging less than 5 per cent and ranging from 0-30 per cent among families. The occurrence of a few second-diapause larvae in insectary rearings, where conditions are close to natural and the larvae are fed fresh foliage (I. M. Campbell, unpublished observations), signifies that this behaviour in eastern budworm is not just a consequence of laboratory rearing. Moreover, a small percentage of eastern budworm reared in the mountainous regions of British Columbia, where two-year cycle populations occur, also have this second diapause and may survive a second winter thereby (3). It therefore seems likely that it occurs naturally in wild populations, although it is generally undetected. A similar conclusion was reached concerning *non-diapause*, which occurs under certain conditions (7).

The difficulties encountered in instar determination of eastern second-diapause larvae obviously result from their small size, which is considerably below that of normal fourth-instar larvae. Judging from their head-capsules (Fig. 3, Table I), insects entering second diapause are already somewhat smaller than average, although this, in itself, accounts for only a small part of the total size deficiency. The fact that, at the establishment check, most developing larvae are found to have reached the fourth or fifth instar, while diapausing larvae are still in their third instar, may signify that the latter not only stop feeding during the third instar but that their development rates are somewhat slower from the time of emergence. There is also evidence from rearing records that second-diapause larvae usually emerge from their hibernacula later than their sibs that develop without delay. These observations are consistent with the theory that insects requiring a period of diapause have lower growth and metabolic rates than those that do not (1).

Most of the size difference between diapausing and normal fourth-instar larvae arises, however, from the failure of the former to achieve the usual size increase in their pre-diapause moult. In both field- (2, 10) and laboratory-reared budworm from eastern populations, each successive instar after the second is some 40-60 per cent larger than the previous instar. The average increase in head-

capsule size of fourth-instar larvae entering diapause was about 18 per cent in the material studied, while the average number of crochets did not increase. Since entry into a second diapause is not normal for eastern budworm, the question arises as to whether the small size increase is another of the unusual characteristics of this behaviour, or whether it is typical of the moults leading to diapause. From Table I it is plain that the latter is the case, all moults associated with a diapause resulting in reduced size increments. In both eastern and western two-year cycle budworm the second-instar larva is only about 20 per cent larger than the first instar. A similar size increase accompanies the moult of third-instar larvae to diapausing fourth-instar larvae in the two-year cycle type, where this is the normal behaviour. Crochet counts of diapausing larvae from western two-year cycle populations are not available for comparison, but the increase in crochet number reported for second-instar eastern budworm (10) is very small and probably insignificant. Thus, when a moult takes place at the beginning of a diapause, it produces only minimal size changes in the larva. Similarly reduced size increments accompany pre-diapause moults in *C. murinana* (Hbn.) (15) and *C. conflictana* (Wlkr.) (11). One character common to these species is the reduction in the period of food intake during the pre-diapause instar. In both types of *C. fumiferana* and in *C. murinana* the first-instar larva does no feeding, surviving on the food reserves of the egg; *C. conflictana* does some feeding in the first instar, which probably accounts for the somewhat greater than minimal size-increase achieved at the first moult. In both eastern and western *C. fumiferana* about to diapause a second time, feeding continues only part way through the third instar. It is not surprising, therefore, that only a limited increase in size is attained at the pre-diapause moult in these insects.

The ecdysis associated with the first diapause of the spruce budworm appears to occur about mid-way through the course of the visible changes leading to diapause (7). Some reduction in activity and hibernaculum construction precede it; most of the body-size reduction and the associated colour changes occur after moulting has been completed, as visible evidence of continuing internal changes. The second diapause differs somewhat in that the moult comes almost at the end of a similar series of changes, the first obvious sign of which is the cessation of feeding. Since neither moult is a consequence of the increase in size that accompanies normal growth, one is led to conclude that both are a part of the physiological processes which culminate in the diapause that follows. Hibernation in the middle instars, although not particularly common, occurs in a number of insects (1, 8), often toward the close of the instar, which suggests that there may be other examples of diapause beginning with a moult. Further consideration of this type of moult and of its possible place in the processes that lead to diapause, though outside the scope of the present work, might yield interesting information on both diapause and ecdysis.

Much remains to be learned of the nature of the relationships between eastern one-year and western two-year types of budworm. There are differences in genetic constitution (4, 14), morphology and diapause behaviour that support a definite taxonomic distinction between them (for present taxonomic position see (6). The proclivity of budworm from eastern populations towards a second diapause is, on the other hand, in agreement with other evidence of the closeness of the relationship between the two types. In some interior valleys and in the coastal regions of British Columbia, spruce budworm are found that, although resembling the eastern populations in having a one-year cycle, are sufficiently different in other characters to be considered as a distinct, 'western', one-year cycle type (4). Some individuals of this type also enter a second diapause in the

fourth instar under certain field (3) and laboratory (4) conditions, a fact which must also be taken into account in any consideration of the relationships within the species. Although experimental manipulation of the normal diapause pattern was undoubtedly responsible for some of the second diapause described herein, it cannot account for the regular occurrence of this behaviour in laboratory and insectary rearings of both one-year cycle types. Nor would it explain the occurrence of this second interruption in development in predominantly the same developmental stage in all three types, an occurrence that suggests a common origin for this behaviour. The situation may best be described by saying that the diapause behaviour is one of several polymorphic characters found in this taxonomic group, with each member population sharing the basic genetic possibilities but evolving towards its own type and frequency of expression.

Summary

A low incidence of a second diapause has been found in all laboratory and insectary rearings of spruce budworm from collections in eastern Canada. Head-capsule measurements and crochet numbers show that, although this diapause occurs at the beginning of the fourth instar, most diapausing larvae are close to third instar in size. The general behaviour and appearance of the larvae is otherwise very similar to that of the two-year cycle budworm found in certain areas of British Columbia. Although but few larvae survive cold storage, those that do produce apparently normal adults.

The tendency to undergo a second diapause appears to be inherited, but there is also evidence of environmental control. Its occurrence in eastern budworm is of considerable interest, showing that this behaviour is not an exclusive peculiarity of the western two-year cycle budworm.

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Suppression of Oviposition Rate of *Scambus buolianae* (Htg.) (Hymenoptera: Ichneumonidae), in Fluctuating Electrical Fields

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It was suspected for many years that the electrical environment stimulates insect activity. Schùa (1952) found that alternating potentials caused guard bees to become hostile and foragers to increase their activity and food uptake. Levengood and Shinkle (1960) reported that the progeny yields of cultures of *Drosophila melanogaster* Meig. in an electric field were, on the average, higher than control groups and the effect of barometric pressure was considerably reduced. The present study was made to determine whether electrostatic fields of low intensity affected the oviposition rate of a hymenopterous parasite.

Materials and Methods

Scambus buolianae (Htg.), a parasite of the pine shoot moth, *Rhyacionia buoliana* (Schiff.) (Lepidoptera: Olethreutidae), was used in these tests. It will oviposit on laboratory-reared larvae of the wax moth, *Galleria mellonella* L., and coddled larvae of this host were placed in lengths of hollowed pine stem as described by Arthur and Juillet (1961).

Only female parasites from the same population sample and with approximately the same emergence date were selected. They were fed daily on a standard diet of white honey diluted in an equal volume of distilled water containing one per cent red pine pollen by volume (Leius, 1960) and on any juices that they might have obtained from the host larvae. Each morning the insects were fed, and in the late afternoon the eggs were counted and fresh host material placed in the cages and water added to the food pads.

The experiment was designed as four treatments running concurrently for 15 days as follows: (a) shielded from natural ambient electrical fields; (b) exposed to the natural ambient fields; (c) exposed to a constant field of 1.2 v/cm. positive and shielded from other ambient fields; and (d) exposed to a fluctuating field of 0.8 v/cm. $\pm$ 0.4 v/cm. positive and shielded from other ambient fields. Within each treatment were 10 mated females, each in a separate wooden cage, 3¼ in.

by 3¼ in. by 2 in. inside dimensions, with a saran screen back and a lucite plastic front. As *S. buolianae* was known to oviposit at a more efficient rate while in the company of other insects, one male was added to each cage. The males did not interfere with the females as the latter were already mated, and they mate usually only once and seem to be unattractive to the males after oviposition begins. Peak egg production periods for the insects was estimated to occur about midway through the experiment.

The values chosen for the electrical fields are those that were found to occur in fair weather and the fluctuations are comparable to those to be found during the passage of a weather system. The values were determined by a needle probe connected to a Keithley Electrometer, model 200 (MEL Sales, Arnprior, Ontario), by a 12-foot length of coaxial cable.

The unshielded insects were exposed to conditions prevailing during ordinary rearing programmes at the Belleville Research Institute. The insects that were shielded from the natural fields and those that were exposed to the constant and fluctuating fields were housed in grounded, double-walled, copper screen cages with a screen of 25-inch mesh. The electrical fields were produced by a variable voltage direct current generator of reversible polarity. The output was connected to a metal plate and the experimental insects were set at predetermined distances between this plate and a grounded plate.

All known factors were constant for all treatments and the cages were randomly changed twice daily within each of the four treatment blocks to minimize any positional effects.

Results

The average number of eggs laid by the insects in the shielded environment was not significantly different (F test) to the number laid by those exposed to the constant field. However, the number in the former environment was slightly less than that in the latter ($83.9 \pm 9.9^*$ vs. $87.0 \pm 9.9^*$). In the naturally occurring fields the average number of eggs laid was significantly less than the average number laid in the shielded environment ($55.9 \pm 8.8^*$ vs. $83.9 \pm 9.9^*$, $P = 0.001$) and in the constant field environment ($55.9 \pm 8.8^*$ vs. $87.0 \pm 9.9^*$, $P = 0.001$). More eggs were laid in the increased and fluctuating field than were laid in the natural fields ($67.3 \pm 8.4^*$ vs. $55.9 \pm 8.8^*$) but this proved not significant. The egg production in the fluctuating field was much lower than either that in the shielded environment ($P = 0.05$) or that in the constant field ($P = 0.01$).

Some of the males died on the sixth day, and all were dead by the twelfth day. All the females seemed healthy until the twelfth day, when several appeared to become rather feeble. None died until the evening of the fourteenth day and by the fifteenth day four had died, one in each treatment block. Cause of death in each case is assumed to have been old age. The eggs produced by the females subjected to the electrical treatment developed normally and the larvae matured and complete metamorphosis took place. The adults of this generation then produced viable eggs.

Discussion

Two explanations may be possible when ten insects in a naturally occurring electrical environment produce 559 eggs in 15 days as against 839 eggs by a similar group of 10 in an environment shielded from the natural fields. An increase in egg production was caused either by an environment relatively free of ambient electrical fields or by the constant nature of this environment. An increased but constant amount of electricity in the environment showed a slightly increased

*Standard error.

egg production, with an average of 87.0 eggs per female vs. 83.9 eggs per female in the shielded environment. As this increase was not statistically significant, it would seem to indicate that, at the values used, the electrical fields *per se* had neither a stimulating nor a suppressing effect upon egg production. Though the group in the artificially fluctuating field produced more eggs than the group in the natural fields (67.3 vs. 55.9) this increase was not significant. The apparent increase could have been due to the chance selection of more efficient egg producers.

In both treatments where the environment was disturbed either naturally or artificially the oviposition rate of *S. buolianae* was suppressed. When the electrical environment was constant, whether shielded from ambient variations or in constant fields of higher than ground potential, the oviposition rate was not suppressed and may have been enhanced.

It is not known how this suppression takes place but it is possible that once the insects become adjusted to their environment they will continue to oviposit without other than normal interruptions to feed or to rest. In the fluctuating fields they were probably under the stress of having to adapt themselves to continuously changing conditions. They were often seen to stop all activity for several seconds during the change in potential. A jolt to the cage, a change of light intensity, a blast of air, or an awareness of a moving object produced similar hesitation in activity. It seems reasonable to assume that should fluctuations in the electrical environment occur rapidly and in greater than average amplitude, the insects would not oviposit at the same rate as they might in a constant environment. Cessation of activity with a fluctuating electrical field has been shown by Edwards (1960) to occur with adult *Calliphora vicina* R. D. In addition, the possibility that the electrical fields might be working in conjunction with other unknown factors must not be dismissed.

Summary

Scambus buolianae (Htg.) deposited more eggs when shielded from naturally occurring electrostatic fields than when not shielded. They also deposited more eggs when exposed to a constant field of 1.2 v/cm. positive than when exposed to a fluctuating field of 0.8 v/cm. $\pm$ 0.4 v/cm. positive. There was no significant difference between the number of eggs laid in the shielded environment and in the constant electrical field. More eggs were deposited in the enriched and fluctuating field than under prevailing laboratory conditions but this proved not significant. It would appear that fluctuating electrical fields, either of artificial or natural origin, disturb the insects while they are ovipositing and so the oviposition rate is suppressed. Some slight evidence would, however, indicate existence of a stimulating effect produced by the enriched electrical environment.

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Metrioptera (*Roeseliana*) *roeseli* (Hagenbach, 1822) f. *diluta* (Charpentier, 1825) in the Montreal Area (Orthoptera: Tettigoniidae)

By D. Keith McE. Kevan[1]

A few years ago, Urquhart and Beaudry (1953) published the first North American records of *Metrioptera* (*Roeseliana*) *roeseli* (Hagen.) which had been discovered near the Montreal airports in July, 1952 (Ville St. Laurent, 12.VII.-1952, 3 ♂) (Professor Beaudry (in litt., 1960) actually cites 4 ♂); Montreal, 16.VII.1952, 1 ♂; 19.VII.1952, 1 ♂). It was suggested that the species had been introduced by aircraft at some previous date. Subsequently Professor Beaudry (*in litt.*, 1960) has taken the species in suitable grassy localities at several points on Montreal Island (Montreal, 7.VII.1953, 1 ♂; Ste Geneviève, 15.VII.1953; Mount Royal, 9.VII.1959, 1 ♂;) and the neighbouring islands of Ile Perrot (1.VII.1953, 7 ♂, 1 ♀; 3.VII.1953, 1 ♂, 3 ♀) and Ile Jesus (St. Martin, Laval Co., 7.VII.1953, 1 ♂)[2]. He has also encountered it subsequently all around Montreal; at Bois-des-Filion (just on the mainland north of Ile Jesus) it was "very common" during the summer of 1960.

In addition to the specimens recorded by Prof. Beaudry, two males were collected at Rougemont (on the southern Quebec mainland, about 25 miles in a direct line east of Montreal) by the entomological staff of the Canada Department of Agriculture Research Laboratories at St. Johns, Quebec (30.VI.1954 and 6.VI.1955). Dr. E. J. LeRoux (personal communication) also indicates that the species was common at Rougemont during the summer of 1960.

The records would therefore suggest that *M. roeseli* was indeed extending its range, as predicted by Urquhart and Beaudry (*l. c.*), and that it was doing so quite rapidly—unless, at the time of its discovery, it was already more widely distributed than was supposed. It is interesting to note, however, that the military aerodrome of St. Hubert is not very remote from Rougemont and could also have acted as a point of introduction, but it is also interesting to observe that the Rougemont specimens taken in 1954 and 1955 were both fully macropterous (f. *diluta* (Charp.)), and might have flown thither from some other focus—the Ste Geneviève and Mount Royal individuals recorded by Beaudry were also macropterous.

Apart from the four mentioned above, all the specimens of *M. roeseli* so far taken in Quebec have been of the typical brachypterous form commonly encountered in Europe, and hitherto there has been no published record of the macropterous f. *diluta* in North America. During July, 1960, however, numerous fully macropterous specimens were collected among fairly short grass on the Macdonald College campus, Ste. Anne de Bellevue (opposite Ile Perrot, at the extreme western end of Montreal Island), where the species had previously been unrecorded. In fact all the material collected, with but one exception, was of this form. Mr. L. Jobin collected large numbers of specimens, the majority of which were kept in captivity but, unfortunately, did not survive. The data for specimens actually preserved are as follows:—10-12.VII, 4 ♂, 3 ♀ (*L. Jobin*); 13.VII, 1 ♀ (*D. K. McE. Kevan*); 14.VII, 1 ♀ (*S. M. Kevan*); 15.VII, 1 ♂ (brachypterous), 1 ♀ (*M. K. Kevan*); VII. 1960, 7 ♂ (*M. K. and S. M. Kevan*), 2 ♀ (*B. Cooke*).

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[2]The following specimens are also in the Department of Agriculture, Quebec: Ile Perrot, Cté. Vaudreuil, 1.VII.1953, 1 ♀; Montreal, 8.VII.1953, 1 ♀ (both *J. R. Beaudry et F. Godbou*).

On 18th July, also, a widely publicized "invasion" of central Montreal City by grasshoppers, reported in newspapers as far afield as Nova Scotia, occurred (see, for example, Anonymous, 1960). The species involved in this "invasion", were, as is often the case with such incidents, mixed (although most of the grasshoppers collected were *Melanoplus bivittatus*), but one sample contained two macropterous specimens of *Metrioptera roeseli* (♂, ♀, 20.VII.1960, *B. Cooke*)!

It thus seems desirable to record these unusual occurrences of the macropterous form: unusual, not only because *f.diluta* has not hitherto been noted from North America, but also because it is by no means common in Europe. According to Zeuner (1941) the macropterous form of *M. roeseli* occurs throughout the Old World range of the species (Spain, France and England, eastwards to Central, East and Southeast Europe as far as the southern Urals and beyond into western Siberia)[3], but he states that it is rare. In some years, however, it may be locally plentiful, or at least not uncommon (Ramme, 1931; Ebner, 1951; Harz, 1957), and in France, although it is said to be rather rare, it has been recorded from a large number of localities (Chopard, 1951). The present records are of further interest because the macropterous form predominated, a search for brachypterous specimens resulting in but a single capture. In Europe, such an occurrence is, so far as I am aware, unknown, even when *f.diluta* is plentiful (*cf.*Ramme; Ebner, *ll.cc.*).

Ramme (1931; 1951) is of the opinion that cool soil conditions and a humid environment are favourable for the development of the macropterous form and that those found under drier conditions are probably immigrants. Ebner (*l.c.*) agrees that macropterous forms are associated with a moist environment. Conditions at Ste. Anne de Bellevue during the spring and early summer of 1960 were, however, not unusually cool or damp; not does it seem probable, although the Macdonald College campus does not present a particularly moist environment, that the specimens were immigrants, since the macropterous form was found for the first time almost simultaneously with the brachypterous one. That macropterous individuals do migrate is suggested by their appearance in central Montreal. Ramme (*ll.cc.*) notes that specimens which he considered to have migrated often had damaged wings, although Ebner (*l.c.*) is of the opinion that the wings become damaged merely because their unusual length makes them unwieldy. The Montreal male was very battered and some of the Ste. Anne's specimens were also damaged, but the majority were not.

The occurrence of large numbers of the macropterous form, which may perhaps be regarded as a dispersal phase, may conceivably help *M. roeseli* eventually to "extend its range over much of the eastern United States and Canada," as predicted by Urquhart and Beaudry (*l.c.*), but this remains to be seen. Before accepting such an hypothesis it should be noted that Ramme (*ll.cc.*) found that macropterous specimens of *M. roeseli*, taken at Falkensee in Germany, where they were numerous in July, 1930, had greatly reduced and partially sterile gonads, so that some doubt was cast upon the effectiveness of macropterous individuals in establishing the species in other areas. Chopard (*l.c.*), while not disputing Ramme's evidence, points out that any generalization regarding this matter in respect of macropterous *Metrioptera* as a whole required verification. In fact, when two macropterous females of *M. roeseli* from Ste. Anne's were dissected[4], they were found to have well developed ovaries full of eggs. Unfortunately it was not possible to examine males or other females, but this

[3]Although Zeuner does not say so, *M. roeseli* is also found as far north as Denmark, but it occurs only in southeast England.

[4]One by Mr. V. R. Vickery whose assistance is gratefully acknowledged.

would suggest that in eastern Canada, at least, f. *diluta* could prove to be effectual in establishing the species further afield.

It is also interesting to record a late occurrence of the species for Montreal Island. Mr. V. R. Vickery collected a very undersized, very brachypterous female in a grassy field on the edge of Senneville woods, near Ste. Anne de Bellevue, on October 1, 1960. This indicates that, in Canada, the seasonal occurrence of *M. roeseli* is similar to that in Central Europe, namely from early July until the beginning of October (cf. Harz, 1957; 1960). The most recent study of the biology of this species is that of Cejchan (1960).

This recent, successful introduction of a European decticine into North America is not unique. Strohecker (1955) records the occurrence of a rather close, macropterous relative of *M. roeseli, Platycleis* (*Tessellana*) *tessellata* (Charp.) in California. This species (possibly brought in with nursery stock) has become established and is extending its range (Harper and Lockwood, 1960). Another recently introduced tettigonioid from Europe is *Meconema thalassinum* (DeGeer) (Meconematidae), which has been found on Long Island (A. B. Gurney *in litt.*, 1959; *in press*); this could doubtless survive in eastern Canada if the opportunity presented itself.

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Nomenclature Notice

INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE

Notice of proposed use of plenary powers in certain cases (A. (n.s.) 47)

In accordance with a decision of the 13th International Congress of Zoology, 1948, public notice is hereby given of the possible use by the International Commission on Zoological Nomenclature of its plenary powers in connection with the following cases, full details of which will be found in *Bulletin of Zoological Nomenclature*, Vol. 18, Part 2 to be published on 14 April 1961.

(1) Validation of the generic name *Enhydrus* Castelnau, 1834 (Insecta, Coleoptera). Z.N. (S.) 398.
(2) Validation of the specific name *akamushi* (*Trombidium*) Brumpt, 1910 (Acarina). Z.N. (S.) 400.
(3) Suppression of the generic name *Doralis* Leach, 1827 (Insecta, Hemiptera). Z.N. (S.) 583.
(4) Suppression of the specific name *lustrica* (*Paludina*) Say, 1821 (Gastropoda). Z.N. (S.) 730.
(5) Validation of emendations of certain Graptolite names. Z.N. (S.) 983.
(6) Designation of a type-species for *Nemoura* Latreille, 1796 (Insecta, Plecoptera). Z.N. (S.) 1452.
(7) Validation of the generic name *Silo* Curtis, 1833 (Insecta, Trichoptera). Z.N. (S.) 1455.
(8) Validation of the generic name *Mesidotea* Richardson, 1905 (Crustacea, Decapoda). Z.N. (S.) 412.

Any zoologist who wishes to comment on any of the above cases should do so in writing, and in duplicate, as soon as possible, and in any case before 14 October 1961. Each comment should bear the reference number of the case in question. Comment received early enough will be published in the *Bulletin of Zoological Nomenclature*. Those received too late for publication will, if received before 14 October 1961, be brought to the attention of the Commission at the time of commencement of voting.

All communications on the above subject should be addressed as follows:

The Secretary,
International Commission on Zoological Nomenclature,
c/o British Museum (Natural History),
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W. E. China
Assistant Secretary
International Commission on
Zoological Nomenclature

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